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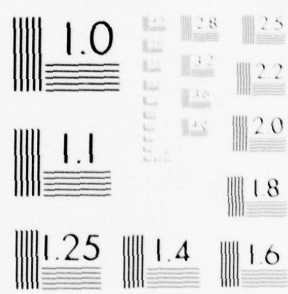
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HELICOPTER AIR TRAFFIC CONTROL OPERATIONS

MAY 1979

FINAL REPORT

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16. Abstract

The problems which inhibit the integration of IFR operations in the ATC system were examined, and recommendations were made to resolve these problems. Revisions in TERPS criteria and in the ATC Handbook are necessary, to minimize interference between fixed-wing and rotary-wing aircraft. The use of 2 nm radar separation between IFR helicopters in terminal areas is recommended to increase capacity by reducing the time interval between helicopter approaches to a value consistent with the time interval between fixed-wing approaches. Helicopters have a special need for low-altitude RNAV capability and the ATC system needs to be better adapted to handle the random route traffic that helicopters will generate in exploiting their special capabilities. To this end, it is recommended that the FAA develop software to call up and display, on the ATC PPI, random waypoints and connecting routes, on an as-needed basis.

Helicopters operating offshore and in remote areas are often beyond the coverage of surveillance radar, thus requiring the use of procedural control. They also operate below the coverage of VHF communications and VOR/DME, requiring alternate types of systems, several of which are recommended. The need for special controller training in procedural control, and in helicopter characteristics and limitations was made apparent during the study.

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METRIC CONVERSION FACTORS

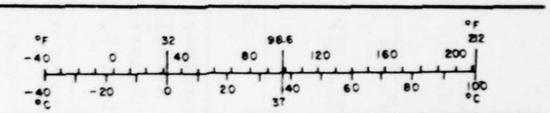
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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EXECUTIVE SUMMARY

This report describes the study which was made, as part of the FAA Helicopter Operations Program, to determine the ATC problems involved in IFR helicopter operation, in intercity corridors, offshore routes, and remote areas. Potentially applicable technology and procedures for solving these problems were then examined and evaluated. The report concludes with recommended short-term and long-term solutions to these problems.

The IFR helicopter is a comparative newcomer in the ATC system, which has evolved over the years in support of fixed-wing aircraft operations. The present ATC system is not prepared to handle the anticipated growth in IFR helicopter operations. The performance characteristics of the helicopter are quite different from those of fixed-wing aircraft; this is especially true in the terminal area, where the slow approach speed of the helicopter makes it difficult to integrate in a landing sequence with conventional fixed-wing aircraft.

The helicopter operates most efficiently at low altitudes, and its flexibility enables it to use many more landing sites besides established airports. To exploit its unique advantages most efficiently, the helicopter needs to fly direct routes to many more sites than those normally used by conventional fixed-wing aircraft. Many of these sites will be off the established airways.

The ATC system is not well adapted to the control of low-altitude traffic, as the VHF communication system, the VOR/DME navigation system, and the radar surveillance system are all subject to line-of-sight propagation limitations. As a result, their useable range at low altitudes is relatively short. Consequently, helicopters operating in their preferred environment are often outside the coverage of these three systems, particularly in offshore and remote areas.

Also, the ATC system is not well adapted to deal with random-route operations; a basic problem is the controller's difficulty in visualizing flight routes between waypoints which are not shown on his video map. However, trying to show all possible waypoints all of the time would simply create a confusing clutter problem; for example there are 2400 offshore helicopter platforms in the Gulf of Mexico, any one of which could become an origin or destination waypoint for a medical evacuation flight.

A possible solution to the random route problem is for the FAA to develop software which would permit selected random waypoints, and the direct routes connecting these way-points, to be called up on the display only as needed, using either lat-long or rho-theta coordinates, with either a manual input, or preferably by the ATC computer from the flight plan.

There is a need for specialized controller training in helicopter characteristics and limitations, and also in non-radar control procedures. The study also revealed the need for revisions in the TERPS manual and in the ATC Handbook, in order to take advantage of the helicopter's unique performance characteristics, and to reduce interference between helicopter and fixed-wing traffic. A 2-nm separation standard between helicopters at approach speed would increase capacity and tend to equalize the approach intervals of fixed and rotary-wing aircraft.

Various methods of providing continuous static-free voice communications between controllers and helicopters operating outside of normal ATC communications coverage were reviewed. Possible solutions include troposcatter VHF links between the ATC facility and repeater stations with direct VHF links between repeater stations and helicopters. Ultimately a satellite link might be substituted for the troposcatter link. Less exotic solutions include the use of microwave relay between ATC facilities and repeater stations; or even air-to-air communications in some instances.

To provide aircraft position reporting in areas outside of radar coverage, development of a data link is recommended, to transmit automatically on a roll-call basis position data from the aircraft navigation system, and altitude data from an altitude transducer. An ATC computer would control the interrogations, and would process the incoming data to generate tagged targets on the ATC radar indicator.

It is expected that long-term solutions to OTH (over-the-horizon) communications, surveillance, and navigation problems will involve the use of satellite technology.

The detailed development, evaluation, and implementation of the recommendations listed in this report will form the basis for the next phase of the FAA Helicopter ATC Operations Program.

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1.0 INTRODUCTION

Fixed-wing aircraft and the National Airspace System (NAS) have developed together over the years. The result is a highly sophisticated ATC system which is tailored to support fixed-wing aircraft operations. As a relative newcomer in the ATC system, the IFR helicopter has been forced into an operational and regulatory environment in which the control procedures, criteria, and equipments have been designed for fixed-wing aircraft. Because of the surge in IFR helicopter usage, it is imperative that the ATC system be adapted to control IFR helicopter traffic in a manner which will allow these aircraft to operate more efficiently.

1.1 Purpose

The purpose of this report is to present recommendations on how the Federal Aviation Administration (FAA) should improve the ATC aspects of the NAS in order to support current and projected helicopter operations.

1.2 Scope

Government and industry forecasts anticipate sharp increases in helicopter operations during the remainder of this century. More specifically, almost all helicopter forecasts suggest that the minimum requirements for helicopter services by the year 2000 will be two to three times as great as they are today. This growth in helicopter activities has already begun, and will continue to place additional requirements on the NAS to support helicopter operations.

In anticipation of these additional requirements, the Systems Research and Development Service (SRDS) of the Federal Aviation Administration (FAA) has implemented a helicopter operations development plan in order to solve problems which will result from placement of these requirements. The goal of the plan is to insure the full, safe, timely, and economical integration of helicopters into the all-weather operations in the NAS.

As one of the nine helicopter development areas initiated by the Systems Research and Development Service (SRDS), this study addresses the subject of helicopter operations within the ATC system. The nine areas, which comprise the FAA Helicopter Operations Program, are listed in Table 1-1. The objective of the program is to establish safe, economical, and technically

TABLE 1-1

HELICOPTER OPERATIONS DEVELOPMENT AREAS

o <u>NAS IMPROVEMENTS</u>

Helicopter IFR Model Development
Navigation System Development
Communication System Development
Helicopter Air Traffic Control*
All-Weather Heliports

o <u>AIRWORTHINESS CRITERIA (DOCUMENTATION AND PROCEDURES)</u>

IFR Helicopter Certification
Helicopter Icing Standards
Helicopter Crashworthiness
Helicopter Noise Characterization

*Subject of this report.

feasible procedures, practices and operational concepts that will enhance the orderly implementation of increased helicopter activities in the National Airspace System.

In response to the objective stated above, the following tasks were developed:

1. Analyze and document current helicopter operations, particularly those which are related to Gulf of Mexico offshore oil platform operations, and to the current offshore oil activities in the Atlantic Ocean; i.e., Atlantic City and any other area where a specific request to operate helicopters has been received by FAA (e.g., requests such as that proposed to support operations off Cape Cod);

2. Analyze and document helicopter air carrier and lease/charter operations;

3. Analyze and document point-to-point, and city-center to city-center operations;

4. As a result of the analyses performed in Tasks 1, 2 and 3, above, recommend areas where FAA should concentrate its efforts to improve the National Airspace System; provide material to support any recommendations made. A time-table for action should also be developed so that the near-term and long-term efforts are addressed in one, well-integrated program;

5. Provide a literature review of short Takeoff and Landing (STOL) and Vertical Takeoff and Landing (VTOL) aircraft, paying particular attention to the operations of these aircraft as they relate to current ATC concepts and procedures. Fixed-wing concepts which can be modified and applied to helicopter operations should be reviewed and documented;

6. Define future, representative, helicopter flight characteristics and configurations which can be used as a basis for the definition and optimization of the ATC operational capabilities required to support future helicopter flight activities.

1.3 ATC Considerations

Two main functions of Air Traffic Control are (1) to prevent collisions (a) between aircraft, and (b) between aircraft and the ground; and (2) to expedite the flow of traffic.

Over the years, the ATC system has developed into an exclusively ground-based system, with all control decisions being made by controllers in terminal or enroute ATC facilities. This concept has provided a relatively safe but highly labor-intensive operation.

The provision of separation between fixed-wing aircraft operating under IFR has been designed and built around the use of surveillance radars. Navigation and approach aids, as well as the air/ground communication system, are based on the use of the VHF and UHF bands, which have the advantage of being relatively free of atmospheric noise, but which are subject to line-of-sight cut-off characteristics.

Similar surveillance and communications requirements exist for handling helicopters in the ATC system. Within the ATC system and its procedures are constraints which inhibit full utilization of the helicopter's unique operating characteristics.

2.0 INTERCITY OPERATIONS

2.1 Description

2.1.1 Background

Because of the high cost of helicopter operations, intercity helicopter operations are dominated by flights of corporate aircraft which are used primarily for executive travel. In this application, the high costs-per-seat-mile are compensated for by convenience and savings in travel times of high-salaried personnel. This type of travel is used mainly for trips between company plants or between company plants and major airports, and it is considered "short-haul" (i.e., flight over distances of less than 200 nm in length).

Intercity corporate operations are expected to increase significantly in the future as urban congestion and efficient information exchange foster a trend toward decentralization of offices and industrial plants. This, in turn, will increase the need for inter-plant helicopter transport.

The demand for intercity services provided by scheduled helicopter airlines is also expected to increase in the years ahead. While public acceptance of such services has been at a low level since scheduled passenger service was first inaugurated by New York Airways in 1952, it is anticipated that increasing demands for r pid travel between major urban areas, together with the introduction of faster, quieter, and more dependable aircraft, will see a resurgence of interest in the use of scheduled helicopter airlines. In this regard, some forecasts show by 1980, as many as 30 Sikorsky S-76 helicopters will be in use in the Northeast Corridor (NEC) between Washington, New York, and Boston. By 1981, it is estimated by some that this number could increase to 80 or more to meet the forecasted demand for helicopter services.

The growth in corporate and commercial helicopter services will place ever increasing demands on the FAA to support such operations. The support that is required, however, will be a function of the type of helicopter operations which are to be performed. Accordingly, we will now review the characteristics of enroute and terminal operations as they relate to intercity operations; we will attempt to isolate specific problems which must be solved if the requisite FAA support is to obtain; and we will make specific recommendations relating to the level of support required in each case.

2.1.2 Single-Thread Description

In order to understand better the type of operations involved in intercity flights, it is instructive to examine in detail a single-thread description of a typical helicopter flight in a segment of the Northeast Corridor (NEC).

The NEC is a dual-lane route structure which was established in 1974 as an experimental, low altitude, helicopter route between Washington, New York and Boston. Operation within the NEC is based on VHF Omnirange/Distance Measuring Equipment Area Navigation (VOR/DME RNAV) waypoints. Each waypoint was identified by means of a five-letter designator (for example, HAYER). The lane widths were ±2 nm from the centerline connecting the successive waypoints. Figure 2.1 shows the route layout. As seen here, all waypoints are expressed in terms of latitude and longitude; bearings and distances from appropriate VOR/DME stations are also given. Waypoint data also include the three-letter designator and the frequency of the VOR. The waypoints are relatively close together in order to minimize lateral navigation errors, and thus, to hold the route width to 4 nm.

The flight described below is typical of operations within the NEC, and it will be used to highlight areas where FAA support can augment and enhance current operations.

> Operations begin with the filing of a flight plan for a trip from Mercer County Airport at Trenton, New Jersey, via V313R and the 026° approach to the Wall Street Heliport on Manhattan (the plan is telephoned to the Philadelphia Flight Service Station (FSS); at the same time, a weather briefing is obtained). The FSS forwards the relevant flight plan data to Philadelphia Approach Control as it is this facility which has jurisdiction over the area in which the flight will begin.
>
> Figure 2.1.1 shows V313R from Trenton via JONNS, and the 026° approach via LEXAN, as depicted on video maps. The pilot, as a part of his preflight activities, requests IFR clearance to New York from the Trenton Tower (an FAA

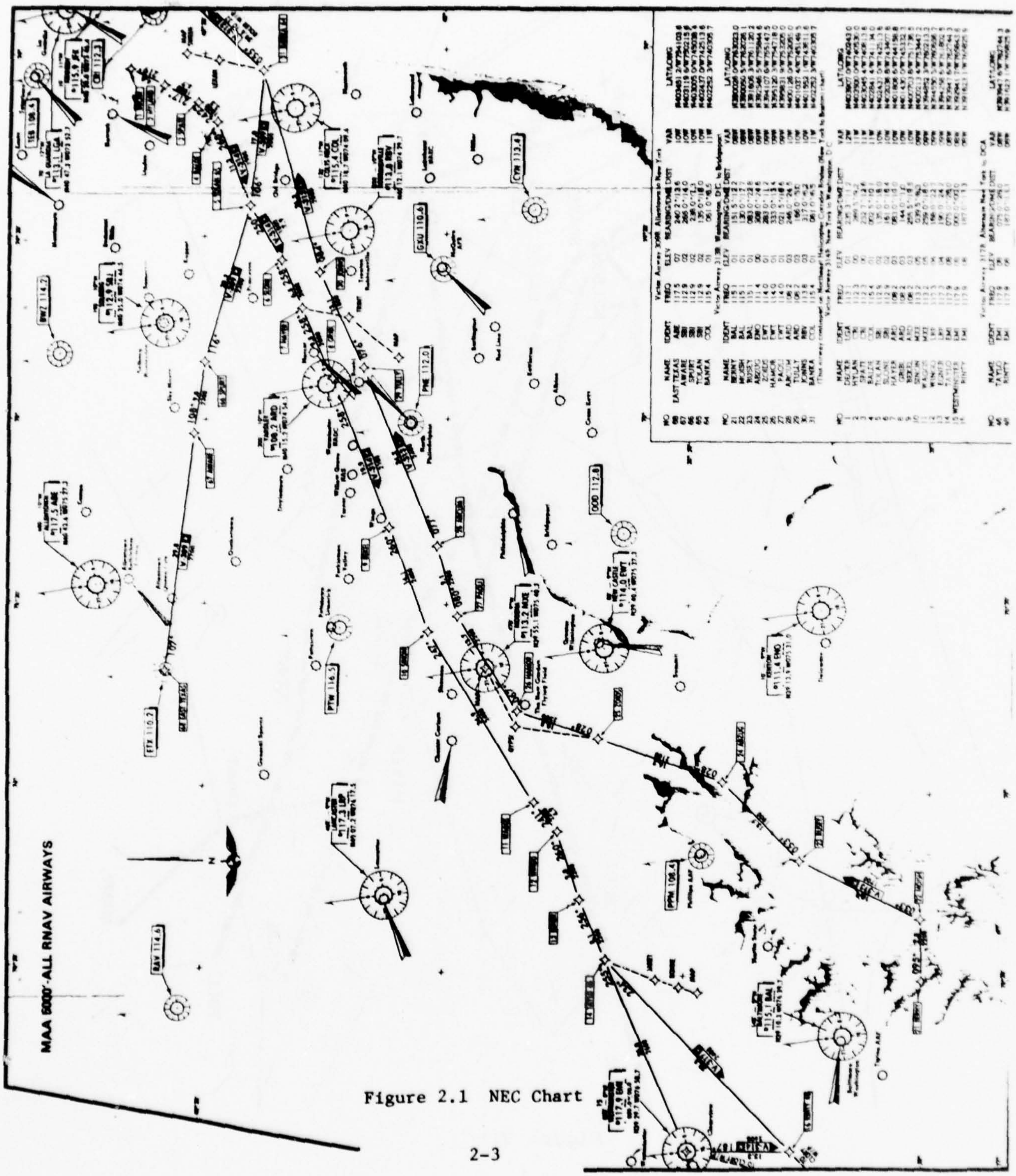
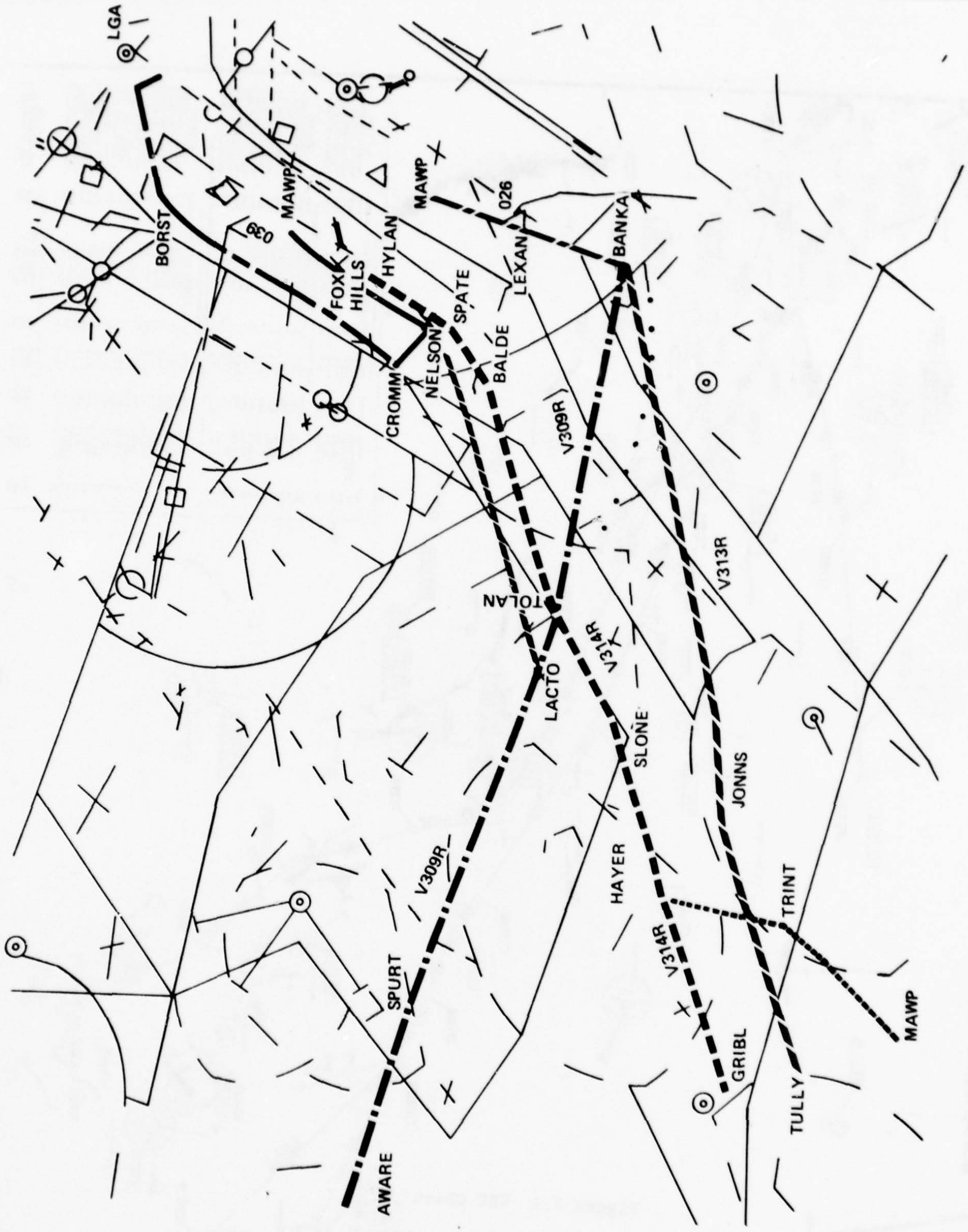


Figure 2.1 NEC Chart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LACTO
SLONE
JONNS
HAYER
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TRINT
V314R
SPURT
MAWP
GRIBL
TULLY
AWARE

Figure 2.1.1

non-approach control facility). The Trenton ground controller now calls the appropriate departure control position at Philadelphia Approach Control, which coordinates with McGuire Approach Control (this is done because the flight will penetrate McGuire airspace within a few minutes after departing). McGuire must coordinate with Kennedy Approach Control (SATES position) for arrival altitude prior to departure. The New York ARTCC is not involved in this flight operation since it had previously delegated control of the airspace to be used to the approach control facilities. Based on current traffic conditions, Philadelphia Approach Control issues a clearance "as filed," which is delivered to the helicopter pilot by Trenton Ground Control.

The pilot now advises the Trenton local control position that he is ready to depart. The pilot is cleared for takeoff to cruise at 3000 ft, and is directed to Philadelphia approach control when local traffic is no longer a factor. Radar contact is established by Philadelphia within one minute after departure, and the flight is radar monitored for the few minutes it is within Philadelphia jurisdiction prior to handoff to McGuire.

Approximately six minutes after takeoff, the flight is under radar control by McGuire Approach Control. Five minutes later, the flight is cleared to descend to 2000 ft. This is requested by ATC because of normal congestion in the Colts Neck VORTAC area at altitudes of 3000 ft and above. McGuire hands the helicopter off to the SATES (Kennedy) Controller nearing the Kennedy airspace jurisdiction. Clearance for the 026° approach should now be given unless there is an opposite-direction helicopter departing Manhattan, or unless a Canarsie VOR 13L/R approach is being conducted. When such traffic exists, a delay in the helicopter's flight will be necessary.

The primary point-in-space approach to Manhattan is the 026° approach. The Kennedy approach controller must coordinate with the LaGuardia approach controller, however, prior to the helicopter beginning a 026° approach. The approach profile is charted beginning at BANKA waypoint and proceeding directly to LEXAN waypoint, a distance of 5.5 nm; the flight altitude is 1800 ft. From LEXAN, the helicopter proceeds 3.8 nm to the missed approach waypoint. Once the decision point has been reached, it is still more than 10 nm to the Downtown (Manhattan) Heliport (note that relatively slow flight speeds may be necessary here if low-visibility conditions exist).

If a missed approach must be executed, the flight under discussion will make a climbing left turn to 1800 ft, and hold SW of the LEXAN waypoint in a left-hand pattern until further ATC clearance is received.

For the return trip to Mercer County Airport, it is first necessary for the pilot to contact the LaGuardia sector on the telephone, and to obtain IFR clearance. Flight routing is direct to the missed approach waypoint, then direct to HYLAN, direct to SPATE, and direct to TOLAN V314/R HAYER. Routing via waypoint BALDE on V314R is too close to McGuire airspace; consequently, BALDE is bypassed by means of a direct route from SPATE to TOLAN; and when using this routing, no coordination with McGuire is required. However, it is necessary to coordinate with the Newark Sector prior to departure.

The flight must now climb to cross the missed approach waypoint at 500 ft or above, and then climb to 1100 ft within 1.5 nm from that waypoint; the crossing at HYLAN is made at 1800 ft. Normal clearance altitude is 2000 ft. The IFR portion of the flight begins during departure when the helicopter reaches an altitude of 500 ft.

Radar handoff from LaGuardia Sector to Newark Sector is accomplished at the SPATE waypoint. When the flight is within the Newark airspace, it is cleared to climb to 3000 ft. Handoff from Newark to Philadelphia is accomplished after the TOLAN waypoint, and prior to STONE waypoint on V314R. The flight is now under control of Philadelphia approach control until the IFR portion is terminated for landing at Mercer County Airport.

At this writing, the NEC is the only special intercity helicopter IFR route in operation. However, it is expected that the NEC will serve as a model for future helicopter routes in other parts of the country wherever, and whenever, demands for such routes are justified. Thus, the "single-thread" description above may serve as a general example of helicopter intercity IFR operations.

2.1.3 Terminal Areas

From the airspace standpoint, the New York Metroplex is probably the most intensively-studied terminal area in the world. A review of the New York Metroplex operation will be used to highlight problems that will be faced in introducing helicopters into congested terminal areas.

The concentration of six major airports in one area has resulted in a very complex layout of approach and departure routes for fixed-wing aircraft. For example, terminal IFR traffic for Newark, LaGuardia, and Kennedy airports (formerly handled by individual approach control facilities at these three airports) are handled in the New York Common IFR Room (CIFRR). The CIFRR has already been doubled in size since it began operations in 1967 so that it could house an ARTS-IA Automated Radar Terminal System. An even larger installation, the New York Terminal Radar Control (TRACON) facility, is now under construction at Mitchell Field. Scheduled to be commissioned in late 1979, it will replace the CIFRR. Using data from four airport surveillance radars, and processing these data using the latest ARTS-IIIA equipment, the capabilities of the TRACON will eventually be expanded to take over IFR control at Islip and Westchester Airports.

In addition to having more capable data processing and display equipment, the New York TRACON will provide better radar coverage, and will reduce coordination problems which now exist between the various airports. These improvements should allow controllers to make more efficient use of the existing airspace; this, in turn, should make it easier that it has been in the past to establish new helicopter routes in the area (particularly in the area between LaGuardia and Westchester, and in the area between Kennedy and Islip). Yet, today, flight operations in the New York Metroplex, as well as in other areas, are designed for fixed-wing aircraft. Approaches to runways, for example, are configured primarily for these aircraft, with little (if any) attention paid to the characteristics and requirements of the helicopter. Further, despite the use of special instrument approach procedures for helicopters at 57 different locations in the U.S., no Standard Arrival Routes (STARs) or Standard Instrument Departures (SIDs) have been published for helicopter traffic.

2.2 Problems

2.2.1 Enroute

Because of the narrow route width used in the NEC (4 nm), the FAA requires individual helicopter pilots and aircraft to be authorized to use the corridor routes. The authorization procedure requires, among other things, a demonstration of the operator's ability to navigate within the 4 nm traffic lanes.

Although it was intended that the restrictions on operations in NEC routes could eventually be removed if the experience gained during a year of IFR operations showed that such operations could be conducted safely, the time, expense, and paperwork required for individual authorization resulted in a paucity of authorized operators. This has severely limited the amount of experience which could be gained in such operations. As yet, the restrictions continue to limit the development of helicopter operations in the NEC.

The low volume of helicopter corridor operations has led to other problems. For example, controllers and pilots lack familiarity with helicopter routes and with helicopter IRF approaches. Changes in waypoints and "experimental" charts which are not up-to-date compounded this problem since controllers and pilots were not always using the same waypoints and charts.

For effective, safe operations, controllers must have ready reference to up-to-date enroute charts and approach data; further, these charts and data should be identical to those used by pilots. However, no single organization has had overall responsibility for maintaining current data on the NEC and its associated spurs (i.e., specially approved branch routes connecting the corridor and the initial approach points).

While perhaps not apparent from the flight operations detailed in Section 2.1.2, the flight described is longer than it would have been if VFR flight routes, rather than IFR routes, had been used. A good example of the difference in route lengths between IFR and VFR routes is the IFR route from Bridgeport, Connecticut, to Wilmington, Delaware, which is 226 nm IFR as compared to 156 nm VFR (a 60 nm, or 36%, increase in distance). Thus, if range limitations are of concern in any given case, a pilot may be forced to go VFR (if weather permits), or cancel the flight. In short, differences between the lengths of IFR and VFR routes in the NEC discourages IFR usage and further slows the accumulation of IFR experience in the NEC.

With respect to the NAS, in general, the prospect of increasing air traffic capacity in congested areas is severely constrained by FAA criteria governing route parameters. These constraints control the minimum spacing between adjacent airways, corridors and navigation lanes which can be used simultaneously in IFR operations without continuous radar monitoring.

To exploit their full capabilities, helicopters operating in instrument meteorological conditions (IMC) will often need to use random (off-airway) routes which are defined by RNAV waypoints in order to get to their destinations more efficiently. In some cases, such operations have been delayed or disapproved because there was no easy way to show such routes and waypoints on ATC radar displays. Regardless, this problem should be addressed by the FAA as part of the larger problem which is related to the implementation of full IFR capabilities for helicopters throughout the NAS.

Complete, precise information on primary and secondary radar coverage in the NEC is not available since it has been only partially flight checked for coverage. All of these deficiencies must be addressed by the FAA at an early date. Although most of the NEC has radar coverage at the minimum

enroute altitudes, there is a known gap between Westchester and Bradley near the Eastern/New England regional boundary. Coverage is not good below 3000 ft in the southwest part of the NEC in the New England region, and it deteriorates even more southwest of Quonset. Coverage is also marginal near the Baltimore/Philadelphia boundary.

Radar coverage gaps such as those mentioned above create situations in which it is necessary to use nonradar procedural separation between departing aircraft following the same route, until altitude separation is established. This means that if two aircraft must operate at the same altitude, nonradar longitudinal separation must be established before the first aircraft reaches the coverage gap. Thus, the traffic capacity of the NEC is greatly reduced where surveillance gaps exist.

2.2.2 Terminal Areas

With respect to the New York Metroplex, it is important to note that planning of the terminal area traffic patterns has resulted in routes which are optimized for fixed-wing Conventional Takeoff and Landing (CTOL) aircraft since these aircraft account for more than 99% of the IFR operation in this area.

Helicopter flights are constrained to operate under rules governing fixed-wing aircraft, so it is not possible to take full advantage of the helicopter's flight characteristics in the terminal areas. This problem will be difficult to solve, in the congested New York environment.

Except for the low-altitude airspace over New York harbor and around the immediate perimeter of Manhattan, the terminal area contains very little airspace which is not already used by fixed-wing aircraft at one time or another (depending on which runways are in use at the various airports). Skyscrapers block much of the airspace over Manhattan itself. As a result, it is extremely difficult to establish IFR helicopter approach or departure procedures in the New York Metroplex which do not interfere with fixed-wing arrivals or departures at one or more airports, and which will not conflict with current Terminal Instrument Procedures (TERPS) criteria, which are based on CTOL performance characteristics.

Radar vectoring is the usual method of sequencing and spacing aircraft. When used at busy airports such as JFK, without approach metering*, it can result in excessively long vector patterns which use many square miles of lowaltitude airspace. If metering were implemented, fixed-wing patterns would be tighter, and some of this low-altitude airspace might then be made available for helicopter traffic routes. This may be a partial solution to the terminal congestion problem.

Terminal problems related to mixing of CTOL and VTOL aircraft clearly required attention. The greatest problem which must be overcome, in this regard, is the information of helicopters and fixed-wing traffic into the same approach and departure patterns. The difficulty here stems from the speed difference between the two types of aircraft in their approach and climbout modes. Given the fact that aircraft flying IFR must never be separated by less than 3 nm if they are at the same altitude (unless the aircraft are making parallel approaches to runways which are separated by at least 4300 ft), the initial separation becomes excessive when a slow aircraft follows a fast one down the same path. On the other hand, unless an appropriate amount of initial separation is used, a fast aircraft will tend to overtake a slow one ahead of it on the same path. The result, in either case, is a loss in airport capacity because of the larger average separations which result, and because of a high controller workload.

Another problem often encountered in the terminal area is that, at some locations, controllers are not familiar with the flight characteristics of helicopters, and therefore, they do not take into consideration the helicopter's flight characteristics which could be used to relieve some of the traffic problems which result from speed differences between CTOL and VTOL aircraft.

> Example: One helicopter pilot reported that he had been placed in the same traffic pattern with a B-747 aircraft, and had been forced to fly a very long, common-approach path. His helicopter, of course, was quite capable of completing its approach from a much shorter pattern.

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*Metering: the regulation of the flow of aircraft from the terminal feeder fixes to match the landing acceptance rate of the airport.

Part of the problem here is that the ATC Handbook makes no provision for the use of radar vectors to intercept the final approach course inside the outer marker.

One special flight characteristic of helicopters which must be taken into account is their relatively low approach speeds. Because of this, the use of the present 3 nm radar-separation standard between helicopters which are making instrument approaches results in relatively low landing acceptance rates.

For example, assume that the ground speed of helicopters on approach is 60 knots. In this case, the interval between successive approaches may be expressed as: $t = 3600\ S/V$, where t = interval in seconds, S = separation in nm, and V = ground speed in knots.

Substituting, $t = 3600 \times 3/60 = 180$ seconds.

The acceptance rate may be expressed as: $N = 3600/t$ where N = acceptance rate (or lane capacity) in aircraft per hour.

Substituting, $N = 3600/180 = 20$ aircraft per hour.

By comparison, fixed-wing jets normally achieve an average interval of about 100 seconds, for an acceptance rate of 36 aircraft per hour.

Thus, the use of a fixed, minimum separation standard which is based on distance, and which does not take into account aircraft speed, is wasteful of airspace and terminal capacity where low-speed aircraft are of concern. Put another way, separation standards determine the minimum time between successive aircraft; the time to a potential collision. However, there is little to be gained by making the interval between low-speed, highly-maneuverable helicopters almost twice as long as the interval between high-speed, less maneuverable fixed-wing aircraft.

Helicopter operational criteria, which have been published in the current TERPS handbook, are based on the early instrument flight experiences of Army helicopter pilots. These criteria appear unduly restrictive with respect to weather minima and to alternate airport requirements in view of recent advances in helicopter instrumentation, stability augmentation, autopilots, navigation and approach aids, as well as of the backlog of instrument flying experience that has been built up by civil pilots, and by military

pilots. Thus, a review of helicopter operational criteria appears long overdue, and such a review should be made at an early date.

2.3 Technical Alternatives

2.3.1 Enroute

A number of problem areas which are associated with enroute intercity operations have been discussed. Candidate solutions to the problems identified are now detailed below.

(a) NEC Navigation

It is suggested that the FAA open the NEC corridor routes for IFR flights by any helicopter operator who has either RNAV or LORAN C equipment, with the stipulation that the navigation equipment be checked previously within a prescribed time period to meet a specified accuracy. If the use of LORAN C is authorized for navigation in the NEC, it may also be appropriate to amend Federal Air Regulations Part 91.25 (which provides for periodic VOR checks) to insure that the LORAN C avionics equipment meets the stringent navigation requirements of 4 nm wide helicopter routes.

(b) NEC Charting

If the NEC and other corridor routes are opened to the public, the waypoints and coordinates should be noted on low altitude radio facility charts and on regional and local maps (different colors should be used so that these data contrast with the standard Victor Airway route data). A major problem in implementing this suggestion, however, is the introduction of chart clutter.

An alternate solution to the charting problem would be for the FAA to issue (or, at least to certify) special helicopter route charts, similar to the experimental NEC chart which was previously produced.

(c) Direct IFR Routes

Because of their inherent flexibility in the choice of operating sites, helicopters (more than any other type of aircraft) should be able to fly on routes off the established airways. Ideally, these routes should be as direct as possible in order to reduce flight distance, thereby conserving time

and fuel. However, in many cases, the use of direct routes will not be possible because these routes may intersect congested terminal areas, or restricted areas, or because of intervening terrain.

One of the main difficulties in implementing direct IFR routes, however, is that the ATC system is not well adapted to handling IFR traffic on random routes, as the waypoints which are needed to define such routes are not displayed to the controller. Thus, one of the most important improvements which can be made to the ATC system is to provide a means by which infrequently-used routes and waypoints can be "called up" by controllers on an as-needed basis.

It should be possible to develop an NAS enroute display with a capability to display geographical sites or waypoints, and the routes between them, through use of either a "canned" flight plan or a manually-entered flight plan. For frequently-used sites or waypoints, identifiers could be an assigned designator or numeric indicator. Little-used or temporary sites could be identified by means of a four-digit number which is related to latitude, and a similar four-digit number related to longitude. In the Continental United States (CONUS), it may also be desirable to reference random sites by means of VOR/DME coordinates.

(d) Route Width

Route width is based on the degree of navigation accuracy which can be achieved on a daily basis by the users of the system. Routes must be wide enough to minimize, if not eliminate, interference between aircraft which are operating in adjacent airways.

It is suggested that route width be defined to include three standard deviations of the demonstrated navigation error, (on each side of the centerline). The demonstrated navigation error is made up of three components:

(1) Radio navigation aid propagation error

(2) Onboard navigation system error

(3) Flight technical error.*

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*Flight Technical Error (FTE) - Flight Technical Error refers to the accuracy with which the pilot controls the aircraft as measured by his success in causing the indicated aircraft position to match the indicated command or desired position. It does not include procedural blunders. (Section 1.e. (10), page 2, ADVISORY CIRCULAR 90-45A, 2/21/75).

The error analyses used to define route widths should draw data from the flights of a large number of aircraft which will use the routes under study.

Theoretically, the narrower the route width, the greater the number of routes which can be fitted into a given air space. However, there is a practical minimum in which further reductions in Flight Technical Error are not possible due to pilot workload. This is a point of particular concern when considering helicopter pilots, and will probably be the factor which ultimately determines the number of routes which can be implemented within a given air space.

If LORAN C is authorized for use in domestic navigation, it is expected that Item (2) above can be minimized by requiring periodic checks of the LORAN C receiver. This would be accomplished in a manner similar to that by which Federal Air Regulations 91.25 presently requires VOR receivers to be checked (i.e., checking the indicated position against the known position).

Flight Technical Error can be minimized by creating a pilot awareness of its importance, and by providing timely and accurate traffic information on traffic in adjacent lanes (this, obviously, will provide a strong incentive to follow the route centerline). Flight Technical Error can also be reduced by eliminating sharp turns in route layouts.

As experience is gained in flying the NEC, and as recordings of many flight tracks are accumulated, an analysis of these data should provide a realistic assessment of the achievable navigation accuracy by helicopters. From this information, practical criteria which can be used to establish route widths for helicopters operating in IMC may be developed.

The problem of fitting additional routes into any terminal area depends upon the allowable route width. The wider the route, the fewer non-overlapping routes can be fitted into a given airspace.

The route width specified for the NEC is based on VOR/DME RNAV criteria published in FAA Advisory Circular 90-45A, "Approval of Area Navigation Systems for Use in the U.S. National Airspace System." The ±2 nm width on each side of the centerlines in the NEC (see FAA Advisory Circular 73-"IFR Helicopter Operations in the Northeast Corridor") is based on the use of VOR/DME waypoints less than 25 nm from the VOR/DME facility (see Figure 1, Appendix D, FAA Advisory Circular 90-45A).

The criteria for route width provides a high degree of protection against collision with other aircraft or obstructions (see Appendix C, FAA Advisory Circular 90-45A) considering the level of navigation accuracy that is achievable, with the measured accuracy of VOR/DME ground and airborne equipment, and judgements as to how pilots actually fly their aircraft.

This route width, of the discrete RNAV Northeast Corridor helicopter airway, has been perceived by helicopter operators and advocates as a problem. This appears to be so because a single, large class of aircraft has had more rigid airborne navigation systems accuracy requirements imposed upon it, to be authorized to operate under IFR in the helicopter corridor, than other classes of aircraft have had imposed upon them to operate on Federal Airways.

There is a historical cause for this perceived problem. Helicopters achieved IFR capability many years later than fixed-wing aircraft. By the time helicopters were ready to operate IFR, the volume of airspace in high-density portions of the NAS, such as the New York Metroplex, was nearly saturated with fixed-wing arrival and departure routes, and holding patterns.

Thus, "in order to effectively construct the Northeast Corridor concept, a ±2 nm route width was necessary in order to fit this structure into the airspace without affecting established airways." (ref. Draft AC 73-"IFR Helicopter Operations in the Northeast Corridor")

The perceived helicopter airway width problem is, however, part of a large, valid problem: airspace capacity limitations in congested air traffic areas. Solutions to this problem must be identified and implemented.

In order to increase the capacity of airspace in congested areas, the following solutions should be explored by the FAA:

(1) Encourage the use of area navigation, with parallel lanes.

(2) Decrease airway widths where technically and operationally feasible.

(3) Implement approach metering in order to shorten low-altitude vector patterns.

(4) Investigate various holding pattern configurations to determine if holding airspace dimensions can be decreased.

(5) Revise TERPS criteria to exploit the special flight characteristics of helicopters.

(e) Dual-Waypoint Holding Patterns

For locations where holding airspace is at a premium, and where all helicopter pilots are using an area navigation system, it is possible that helicopter holding airspace could be reduced if each pattern was based on the use of two waypoints (one at each end; see Figure 2.2.2). Using this type of pattern, the buffer distance which is required need be no wider at one end than at the other.

Note that the use of a second waypoint in the holding pattern would provide an outer limit for the outbound leg. This is in contrast with the use of a standard, single-fix, holding pattern, wherein the outer limit of the outbound leg is determined by means of timing rather than by a definite fix. Since helicopters are more sensitive to wind drift than are typical fixed-wing aircraft, this concept could reduce wind dependent length of the outbound position of the pattern. A positive fix at the outer end of the pattern would also be most useful in preventing an overshoot of the holding airspace, particularly during entry and during the first time around the pattern.

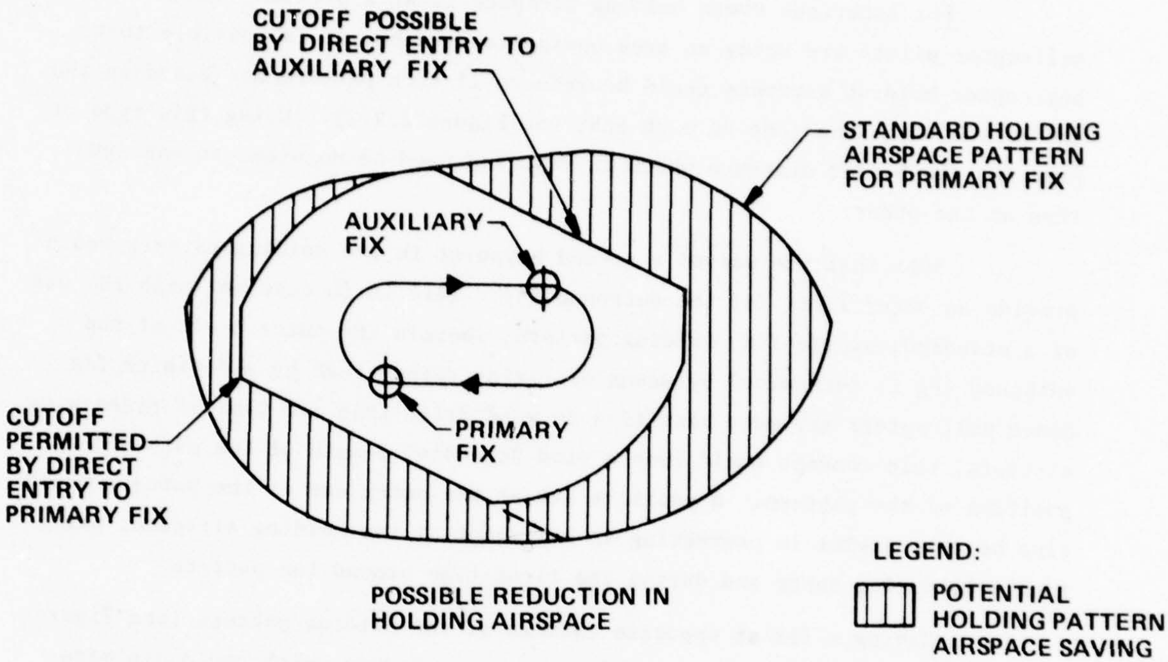
Having a fix at opposite corners of the holding pattern (see Figure 2.3.1) would also provide a simplified entry procedure which could minimize lateral overshoots on initial pattern entry. To enter a right-hand pattern, as shown in Figure 2.3.1, the pilot would head initially for the waypoint to his left. Practically all of the subsequent maneuvering which is necessary to align the aircraft with the pattern in the correct direction would take place inside the holding pattern itself.

In cases where the navigation computer is coupled to an autopilot, and where the computer has the capability to switch alternately between two waypoints, the dual-waypoint configuration would provide the capability of automatic holding.

Finally, the dual waypoint pattern concept shown in Figure 2.3.1 could also provide a safe and positive reference for use as a descent or climbout pattern in confined airspace (such as into, and out of, a heliport or airport which is surrounded by mountains or other obstructions).

(f) Familiarization Training

Helicopter operators and pilots, particularly those engaged in IFR operations, should be encouraged to visit ATC facilities in their operating



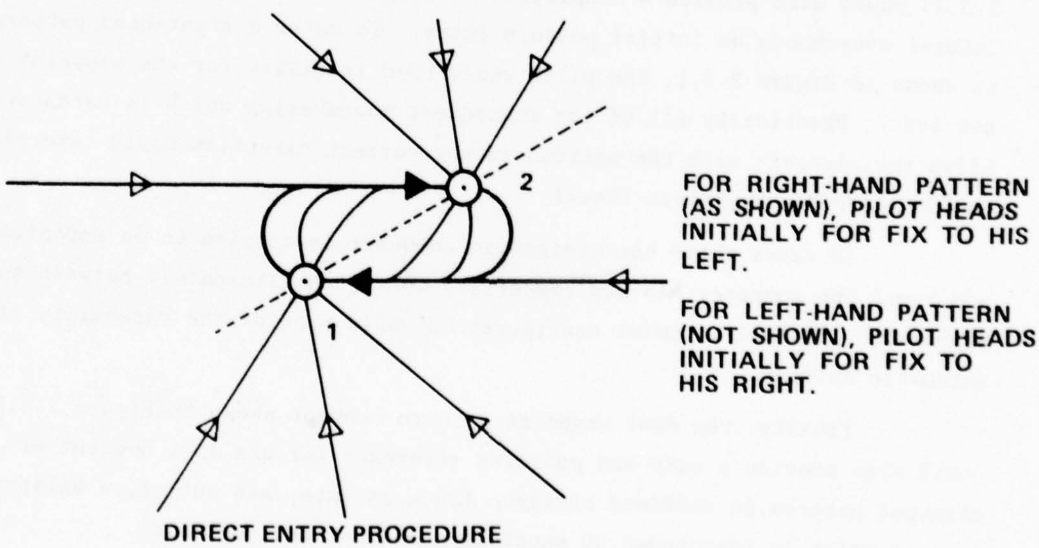


Figure 2.3.1 Dual-Waypoint Holding Pattern

areas for the purpose of familiarizing themselves with ATC demands and operations. Similarly, a short training course on helicopter characteristics and limitations, with particular reference to required helicopter navigation aids, should be prepared by the FAA, and should be administered as part of the training program at facilities where helicopter operations are anticipated. The use of video cassettes would be an ideal means by which to present this material. Where possible, it is also suggested that helicopter cockpit familiarization visits and flights be arranged for key ATC personnel.

2.3.2 STOL Approach Concepts Potentially Applicable to VTOL Operations.

Helicopters constitute the most common class of VTOL (Vertical Takeoff and Landing) aircraft, as contrasted with STOL (Short Takeoff and Landing) aircraft, which are a special class of fixed-wing aircraft akin to CTOL (Conventional Takeoff and Landing) aircraft.

While making an instrument approach, helicopters must maintain a forward speed approximately equal to that of STOL aircraft. Accordingly, one object of this study was to survey techniques for integrating STOL and CTOL approaches, and determine the applicability of these techniques for integrating VTOL and CTOL approaches.

Because VTOL's can decelerate in the air instead of during a rollout on the runway, they do not necessarily need a runway for landing. Thus, wherever possible, integration problems can be avoided by segregating VTOL aircraft in a separate approach stream. However, at many locations this is not possible, because only one instrument approach path is available.

Because of the differences between the approach speeds of CTOL and STOL aircraft, a STOL aircraft which has standard longitudinal separation behind a CTOL at the start of the common approach path will drop farther and farther behind the latter aircraft as the approach progresses, causing an excessive gap to open in the landing sequence (see Figure 2.3.2A). It is suggested that the resulting degradation in airport capacity can be corrected by:

(a) keeping the common path for the two types of aircraft as short as possible; this can be effected by turning the STOL onto a shorter final approach (see Figure 2.3.2B). This procedure appears fully applicable to helicopters, but will require a change in ATC Handbook 7110.65A, Paragraph 790.

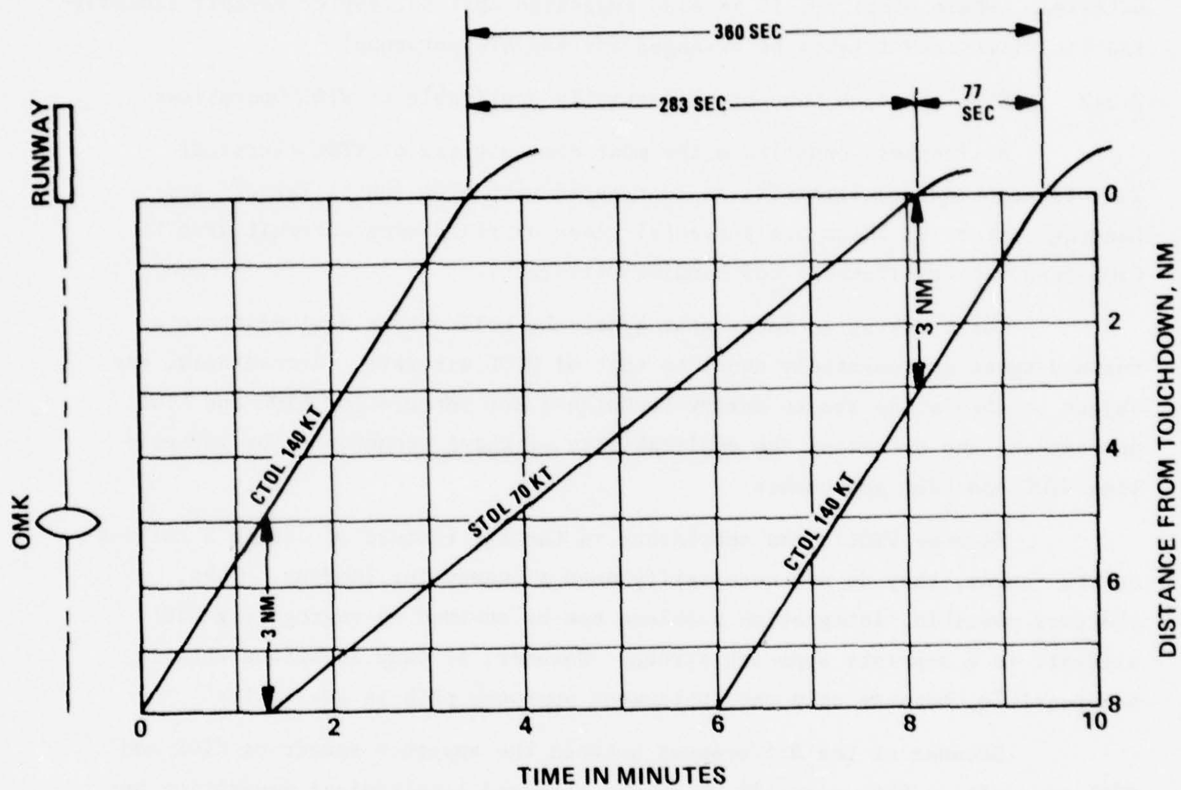


Figure 2.3.2.A With 8 NM Turn-On and 3 NM Initial Separation Behind 140 KT CTOL, 70 KT STOL will have 283-Second Approach Interval at Runway Threshold. CTOL-STOL-CTOL Sequence will Require 360 Seconds.

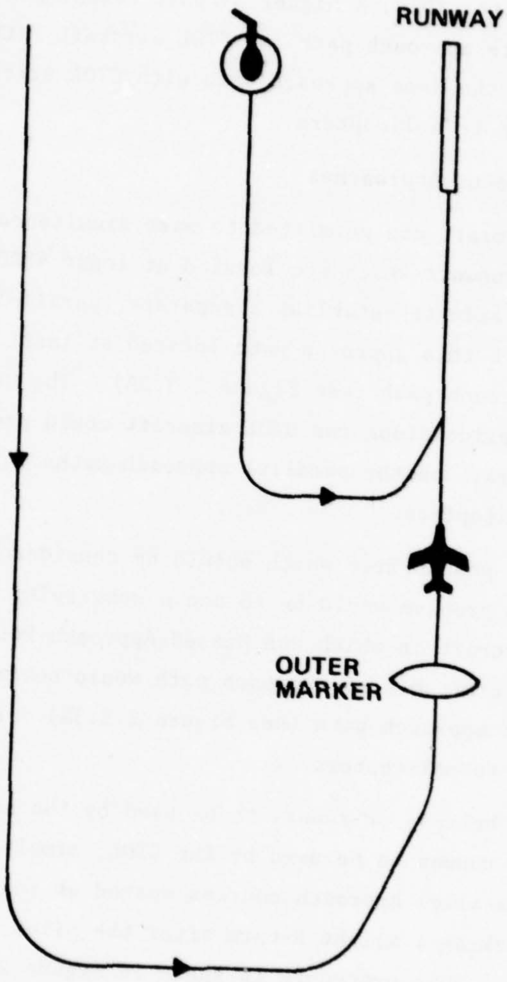


Figure 2.3.2B MINIMIZING LENGTH OF COMMON APPROACH PATH

(b) requesting the STOL pilot to fly at a higher-than-normal approach speed (see Figure 2.3.2C). This procedure may not necessarily be applicable to helicopters.

Whenever possible, a higher airport acceptance rate can be achieved by having a separate approach path for STOL aircraft rather than trying to interleave them into the same approach path with CTOL aircraft. This procedure is fully applicable to helicopters.

2.3.3 Simultaneous Approaches

CTOL aircraft are permitted to make simultaneous instrument approaches to parallel runways which are located at least 4300 ft apart. Thus, it would also appear safe to establish a separate, parallel approach path for STOL aircraft, with this approach path located at least 4300 ft away from the parallel CTOL approach path (see Figure 2.3.3A). The use of runway stagger and/or a steeper glide slope for STOL aircraft could provide additional separation between aircraft on the parallel approach paths. This procedure is fully applicable to helicopters.

Another possibility which should be considered for resolving the terminal approach problem would be to use a converging instrument approach path for STOL aircraft in which the Missed Approach Point (MAP) is so situated that the STOL aircraft missed approach path would never come within 4300 ft of the CTOL aircraft approach path (see Figure 2.3.3B). This procedure is also fully applicable to helicopters.

If the helipad or runway to be used by the helicopter is at least ½ nm away from the runway to be used by the CTOL, simultaneous approaches should be possible on parallel approach courses spaced at least 4300 feet apart, with the helicopter making a slight S-turn after the pilot is in visual contact with the airport. This procedure is shown in Figure 2.3.3C.

For major airports with parallel runways at least 2500 ft apart, STOL aircraft can increase airport capacity and stay out of the trailing vortices of heavy jet aircraft if CTOL aircraft landings are confined to one runway together with STOL aircraft takeoffs. In this case, CTOL aircraft takeoffs would be confined to another runway handling STOL aircraft landings (see Figure 2.3.3D). This procedure is fully applicable to helicopters.

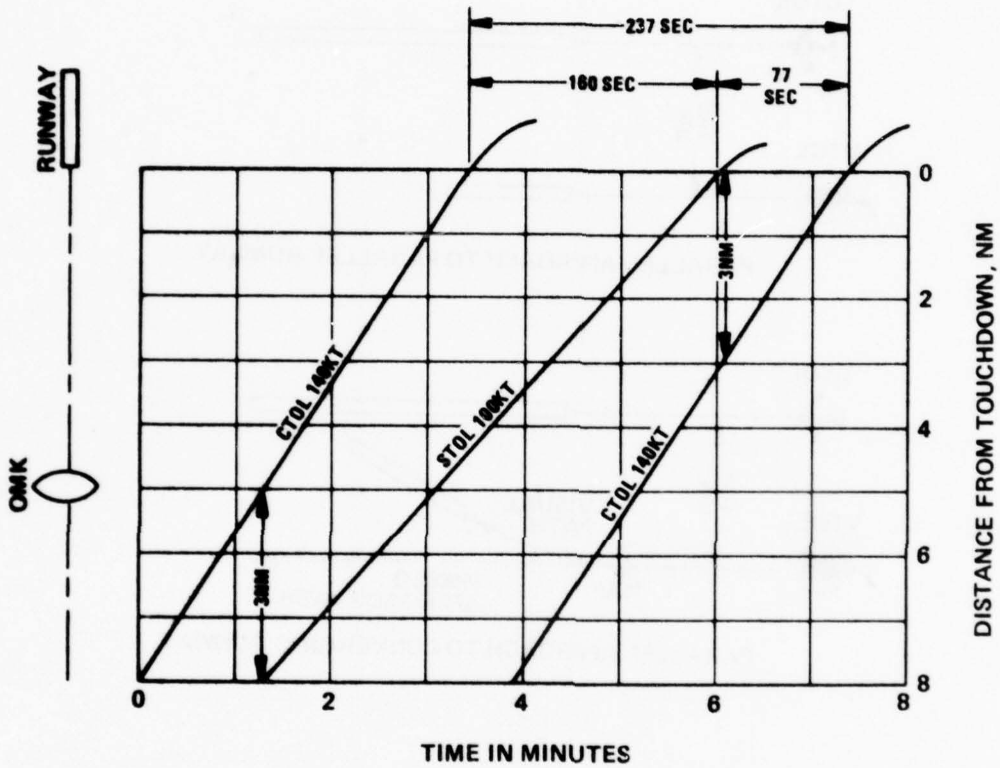


Figure 2.3.2C With 8 NM Turn-On and 3 NM Initial Separation Behind 140 KT CTOL, STOL Speeded up to 100 KT will have 160-Second Approach Interval at Runway Threshold. CTOL-STOL-CTOL Sequence will Require 237 Seconds.

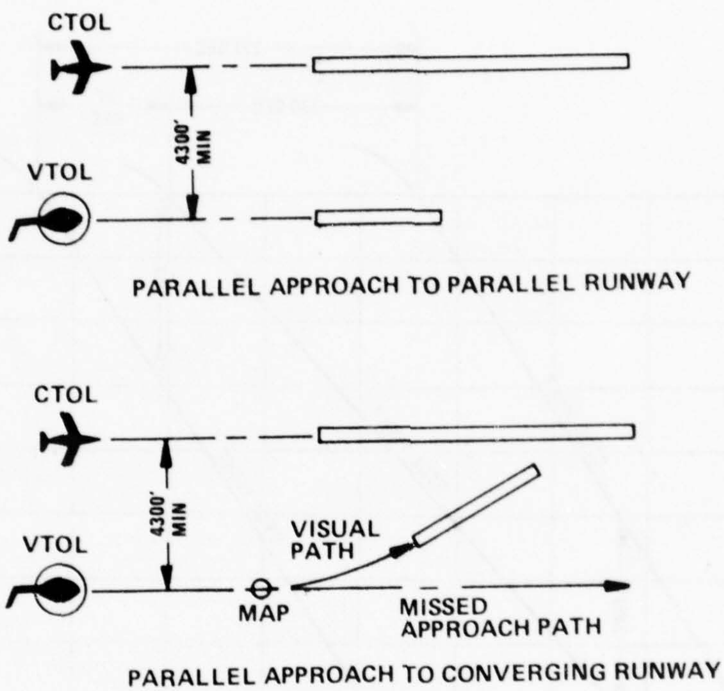


Figure 2.3.3A Parallel Instrument Approaches

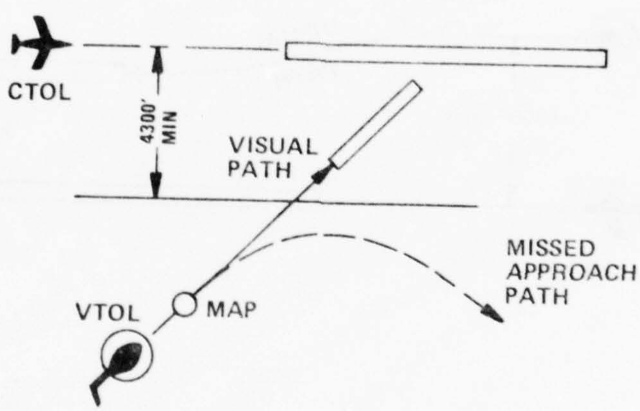


Figure 2.3.3B Converging Instrument Approaches

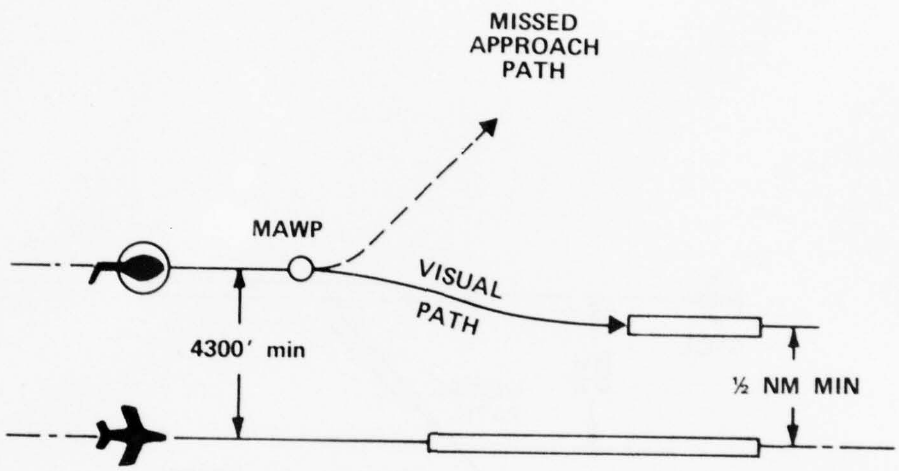


Figure 2.3.3C Simultaneous Parallel Approaches to Closely Spaced Runways

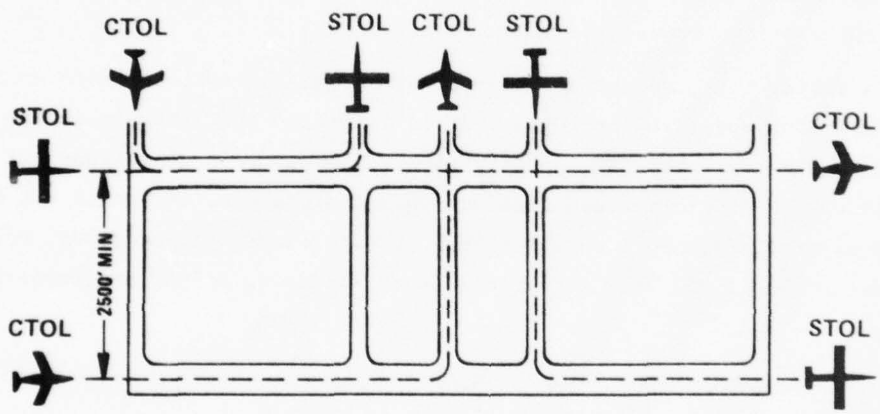


Figure 2.3.3D Vortex Avoidance Procedure
Using Parallel Runways

All of the candidate solutions to terminal approach and takeoff problems which are discussed above use runways which do not intersect. Note, however, that Paragraph 1121 of Air Traffic Control Handbook 7110.65A allows aircraft to land simultaneously on intersecting runways if the intersection is far enough away from the touchdown point to allow at least one aircraft to complete its rollout and to turn off the runway before it reaches the intersection.

An additional concept to be considered is that a long runway exclusively devoted to STOL operations could increase that runway capacity by using it in the tandem mode (see Figure 2.3.3E). In this example, it is assumed that the runway is 8000 ft long, and that the first 3000 ft at each end is marked for STOL operations (for minimum turn-around times which are so necessary for efficient short-haul operations, the STOL terminal ideally would be located near the center of the runway, as shown in Figure 2.3.3E).

Assuming that the use of this runway in the conventional mode would permit 40 IFR STOL operations per hour, it is estimated that its use in the tandem mode would raise the IFR capacity to slightly over 50 operations per hour. Although helicopters could also use such a procedure, it should not be considered particularly applicable for this purpose since, if necessary, helicopters could takeoff and land at various locations along or perpendicular to the runway.

2.3.4 Triple Simultaneous VTOL Approaches

A triple simultaneous approach could be utilized by VTOL aircraft. This concept is based on the capability of these aircraft to make an approach in any direction, and to turn into the wind only for touchdown.

A triple, radial-approach concept would allow VTOL aircraft to make simultaneous approaches on three radial paths to points in space approximately 0.5 nm apart. This concept would exploit the helicopter's capability to make short-radius turns to diverging, simultaneous missed-approach paths (see Figure 2.3.4), or to hover momentarily while waiting to complete a visual landing. As with all other simultaneous instrument approach procedures, it is assumed that this procedure would be used only with radar sequencing and monitoring.

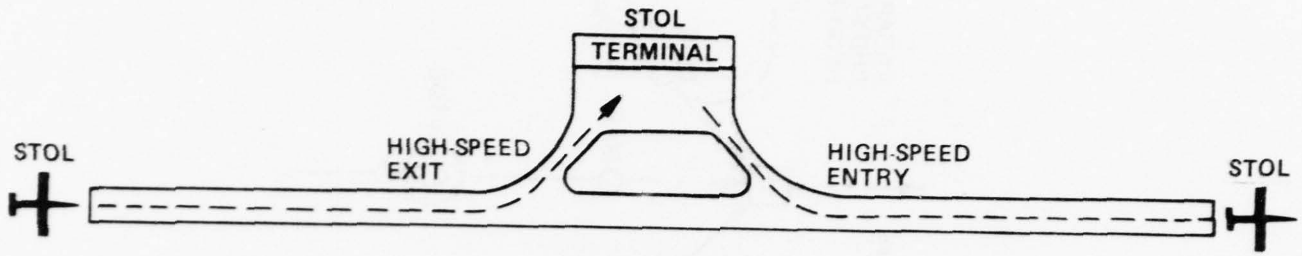


Figure 2.3.3E Use of Single Long Runway in Tandem Mode

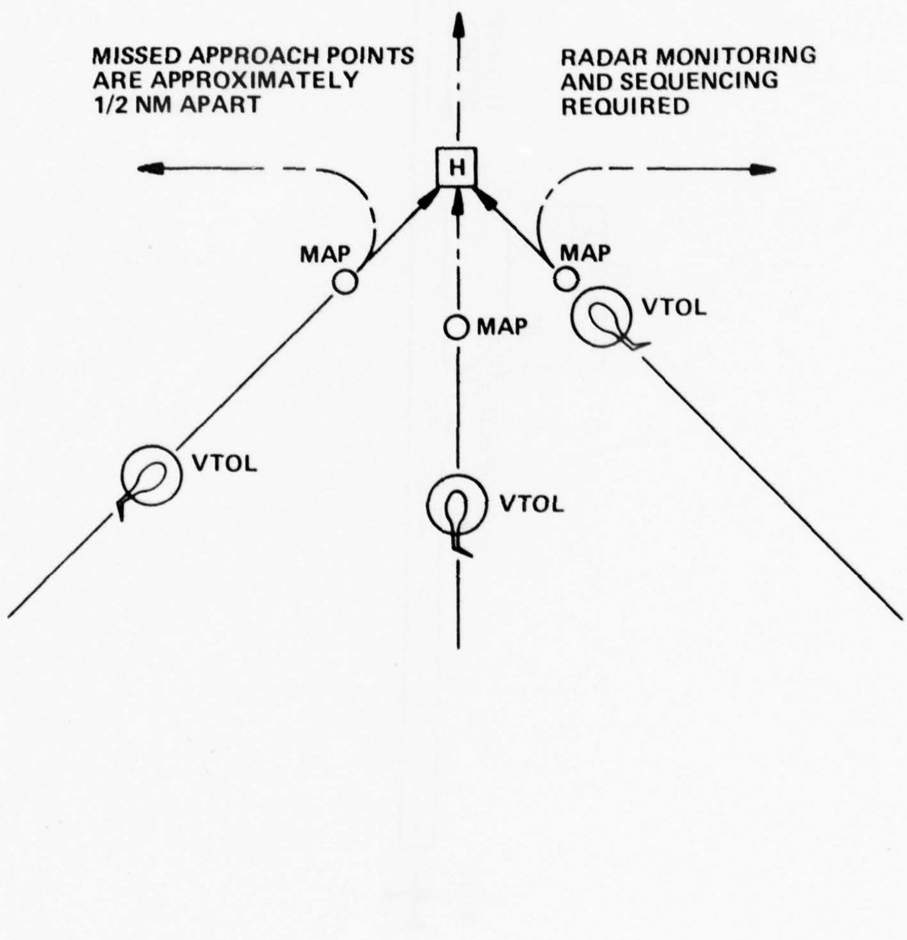


Figure 2.3.4 Triple Radial Approach Paths to Heliport

2.3.5 Use of 2 nm Separation

Where helicopters are concerned, the use of 3 nm radar separation results in excessive approach intervals, which lower the airport acceptance rate accordingly. The use of 2 nm separation between helicopters which are already down to approach speed would provide a 50% increase in landing rate for helicopter traffic.

The time interval between approaches would still be more consistent with the time intervals achieved between higher speed CTOL aircraft. A precedent for the 2 nm standard was made for the helicopters of Los Angeles Airways several years ago.

2.3.6 Microwave Landing System (MLS) Training

The MLS will assist in resolving the problem of integrating short, curved, high-angle helicopter approaches with conventional fixed-wing approaches at locations where these aircraft have to descend on a common path. The basic dynamics of this situation can be explored by means of simulation. In this regard, it would be desirable to provide simulation training to radar controllers in the use of MLS for integrating helicopter and fixed-wing approaches. In fact, at applicable terminal facilities, this type of simulation should become part of the local training program.

2.3.7 Missed Approach Waypoints for Point-In-Space Approaches

One problem with missed approach waypoints for point-in-space approaches (such as the 026° approach to Manhattan heliports) is that they are not generally located so that they are within sight of prominent landmarks. If missed approach waypoints were keyed to prominent landmarks, pilots would have a horizontal reference for visual orientation together with an instant check on the prevailing visibility. This, in turn, would permit them to decide quickly whether conditions would allow them to proceed VFR or Special VFR toward their destination, or whether they should execute a missed approach.

2.4 Conclusions and Recommendations

2.4.1 Enroute

Because the Northeast Corridor routes are only 4 nm wide, the FAA has required individual authorization for pilots and helicopters to use the NEC. The main justification for the special authorization was to make sure

that the pilot and equipment would be able to stay within ±2 nm of the centerline; some General Aviation Inspectors have deemed a 2½ hour flight test as being necessary, while other inspectors have interpreted the requirements more leniently. The more severe interpretations, plus the great amount of paperwork required, have discouraged some operators from applying for authorization. The small number of authorized operators has slowed the buildup of operating experience in this environment, for both pilots and controllers. It is recommended that clear guidelines be established by the FAA to simplify and standardize the authorization procedure.

There has been a problem in maintaining up-to-date enroute charts or approach plates for the NEC and associated helicopter approaches. It appears that no single authority has had overall responsibility for maintaining or publishing up-to-date data and charts on the NEC. It is recommended that a single authority be given responsibility for maintaining and publishing those NEC enroute charts and approach plates needed by pilots and controllers. Funds needed to accomplish this must also be provided.

The short range and the high flexibility in the choice of landing sites increased the need for helicopters to be able to fly direct routes between selected random waypoints, in order to operate efficiently. A significant percentage of these routes would be off the established airways.

Today's ATC system is not well adapted for handling random route traffic between off-airway waypoints. One problem has been the difficulty for controllers to visualize where some of these points are if they are not shown on the video map. However, it would not be desirable to show all of these points on the video map, as this would generate a very confusing problem on the radar scope. What is needed is a method of calling up certain random waypoints for display on the PVD and ARTS displays, on an as-needed basis.

These points could be called up either automatically by flight-plan input, or manually by reference to lat-long or VOR/DME coordinates. Implementation of this capability would enhance the capability of the ATC system to control off-airway traffic; and in doing so would enhance significantly the use of area navigation systems.

The capability to control random-route traffic on a routine basis will determine whether the full potential of IFR helicopter operations can

ever be realized. It is therefore recommended that the FAA begin the implementation of this capability as soon as possible, and that it be implemented on a priority basis.

The use of two waypoints at opposite corners of holding patterns may provide a method by which protected airspace around a holding pattern can be reduced. This concept may reduce overshoots, and simplify holding pattern entry procedures for aircraft equipped with area navigation systems. The positive reference furnished by the dual-fix concept is especially useful for slow-speed aircraft, which are more sensitive to wind drift. The dual waypoint concept also makes possible the implementation of an automatic holding procedure for aircraft with RNAV equipment. It is recommended that the FAA initiate simulation tests of the dual-waypoint concept as soon as possible in order to determine its practicality. If the tests are successful, the concept should be implemented at the earliest possible date.

In general, controllers are far more familiar with the characteristics and limitations of CTOL aircraft than with those of VTOL aircraft. The characteristics of the two types are quite different, particularly as they relate to operations in the terminal area. Also some controllers are not aware of the precautions that should be taken due to downwash problems when helicopters are operating in the vicinity of other aircraft on the airport.

With the increasing use of helicopters, it would be beneficial for controllers and helicopters to become more familiar with each others' operational environment. Helicopter pilots should be encouraged to visit local ATC facilities, while controllers should be familarized with helicopter characteristics and limitations.

It is further recommended that the FAA Academy initiate a course on helicopter characteristics and limitations, including an emphasis on the various types of navigation systems that are being used by helicopters. Precautions for dealing with downwash problems should also be covered. This course should be adaptable for presentation at the facility level, where local helicopter procedures could be appended as necessary. If possible, helicopter cockpit familiarization visits or flights should be arranged to give controllers a closer look at the important elements of helicopter operation.

2.4.2 Terminal Traffic Integration

Whenever airspace and facilities permit, it is recommended that CTOL and VTOL traffic use different approach and departure routes. This should be done in order to avoid the capacity degradation and ATC workload which can be caused by differences in speed between the two types of aircraft. When VTOL aircraft must be interleaved into a common approach path with CTOL aircraft, it is further recommended that the common approach path be kept as short as practicable in order to minimize the effects which result from differences in approach speeds.

It is also recommended that controllers do not request helicopter pilots to fly at an approach speed which is much faster than that which would normally be used, unless the ceiling and visibility are high enough to ensure that the helicopter pilot will have sufficient time to decelerate normally after he achieves visual contact with the surface. In addition, where an airport has parallel runways at least 2500 ft apart, and heavy CTOL aircraft take-offs and landings are segregated on the opposite runway, minimum interference from wake turbulence will result if VTOL aircraft land on the CTOL aircraft takeoff runway, and takeoff from the CTOL aircraft landing runway (this mode of operation is similar to that shown in Figure 2.3.3D).

It is recommended that the FAA examine the foregoing recommendations by means of simulation; and if they are deemed promising, that these recommendations be implemented, and that appropriate material be added to the ATC training program.

2.4.3 Simultaneous VTOL Approaches

A variety of simultaneous VTOL approach concepts are discussed above:

- Parallel Instrument Approaches --- Figure 2.3.3A (includes Parallel Approach to Parallel Runways and Parallel Approach to Converging Runways)
- Converging Instrument Approaches --- Figure 2.3.3B
- Parallel Approaches to Closely-Spaced Parallel Runways --- Figure 2.3.3C

Based on these discussions presented above, the following recommendation is made.

At locations where instrument approach procedures are established to converging runways, the concepts shown in Figures 2.3.3A through 2.3.3C should be used to segregate VTOL and CTOL aircraft arrivals into separate approach patterns for simultaneous approaches. The missed approach points and missed approach paths should be so located to provide a separation of no less than 4300 ft between aircraft flying on instruments.

2.4.4 Triple Simultaneous Approaches to Heliport

For high-capacity heliports where more than two simultaneous approach paths are justified, the triple radial approach concept shown in Figure 2.3.4 is recommended. This concept would provide for the immediate divergence of missed approaches from adjacent paths.

2.4.5 2 nm Separation Standard

It is recommended that ATC Handbook 7110.65A be revised to permit the use of 2 nm separation between helicopters operating within terminal areas at speeds below 90 knots.

2.4.6 MLS Training

The Microwave Landing System offers the possibility for facilitating the integration of CTOL and VTOL aircraft by allowing the latter to make short, curved, steep approaches. Simulation training in the operation of MLS is a practical method by which controllers could gain the necessary experience in interleaving VTOL aircraft which are making short curved approaches with CTOL aircraft which are making conventional approaches to the same runway. It is, therefore, recommended that the FAA conduct simulated and actual flight tests related to the interleaving procedure described above, and using MLS equipment and procedures. The lessons derived from these activities should be publicized as guidelines to terminal facilities and the FAA Academy. Further, the guidelines should be incorporated in simulation training programs for radar controllers at any sites at which MLS is, or will be, installed.

2.4.7 Missed Approach Waypoints for Point-In-Space Approaches

Wherever possible, it is recommended the Missed Approach Waypoints (MAWPs) for instrument approaches to points-in-space terminate near a visually prominent landmark. This is necessary so that a pilot has a horizontal reference

for visual orientation and for determining whether the prevailing visibility will permit him to continue his approach under VFR or Special VFR. This consideration is especially important for approaches which terminate over water.

3.0 OFFSHORE OPERATIONS

3.1 Description

The logistic support of offshore oil and gas platforms involves the transportation of large quantities of material and great numbers of personnel. Originally handled by supply boats, this support has now been taken over almost entirely by helicopters, since the latter can supply fast and reliable transport of personnel on a shift-change basis, regardless of wave height. Helicopters also provide emergency medical evacuation services.

Offshore helicopter operations in support of the petroleum industry in the United States are on-going in the Gulf of Mexico and off the New Jersey coast in the vicinity of the Baltimore Canyon. With respect to work in the Gulf of Mexico, oil and gas exploration, and production, have been in progress for the last 20 years. There are now about 4500 wells in this area; about 2400 of these have helicopter platforms. About 400 small helicopters provide logistic support to these platforms, with most platforms concentrated in an area from 50 to 130 miles off the coast of Louisiana and Texas (the remainder are located off the coast of the Florida Panhandle).

Up to now, almost all of the helicopter operations in the Gulf area have been performed under VFR or Special VFR conditions. Because many helicopters are based at private heliports, a large part of this activity does not interface with the National Airspace System. However, during the winter months, morning fog is a frequent occurrence; further, during this season, low stratus clouds often persist along the shoreline. Because of these conditions, most helicopter traffic is concentrated from the surface up to 1000 feet, and so, IFR operation is the only means by which a helicopter pilot is able to fly at higher altitudes (in or above the clouds) if it is necessary to avoid the low-altitude swarm. This is incentive enough for the use of IFR in the Gulf; another incentive for IFR service in this area, however, is that it will permit operations to begin earlier in the day, before the morning fog lifts.

During the past two years, oil and gas exploration has begun over the Baltimore Canyon off the New Jersey Coast, with drilling in progress on platforms which are located 70 to 100 nm off Atlantic City. The relative severity of weather in this area (as compared to that in the Gulf of Mexico)

mandates an all-weather capability for helicopters used here; this, in turn, implies a strong requirement for IFR service.

Despite the volume of operations in the Gulf of Mexico and over the Baltimore Canyon, there are at present no special IFR approaches for helicopters to the oil and gas platforms in these areas. Action is being taken by FAA, however, to determine the best methods by which to select the equipment and procedures to be used in satisfying IFR requirements. In this regard, it should be noted that approaches have been established for landside departure points, though some operations present special (and, as yet, unresolved) problems because of their over-the-horizon (OTH) locations with respect to their associated departure points. The number of OTH drilling and production platforms will increase as drilling is initiated farther and farther from shore (especially in the Gulf). These remote drilling operations will require support services from large helicopters, and, this, in turn, implies a greater requirement for IFR services.

Because of the expense and complications associated with IFR operations, some oil companies have avoided such operations. However, TENNECO has recently adopted a policy of insisting that all its company helicopter flights be on IFR flight plans; this was done to obtain an added margin of safety and of scheduling reliability. Thus, it appears that a move is under way to certify more helicopters and pilots for IFR operation.

The Baltimore Canyon area is the first area in which extensive IFR offshore helicopter operations have been required. It is expected that most of the operational problems encountered anywhere in the NAS will be encountered here. For this reason, details relating to flight operations in this area are given below.

Offshore routes in the vicinity of the Baltimore Canyon are mostly within Warning Area 107, which is under the control of the Navy. However, in this area the Navy delegates control of the airspace up to 5000 ft above the surface to the FAA on a monthly basis, though it reserves the right to retake control of this airspace, (or any part of it) on short notice.

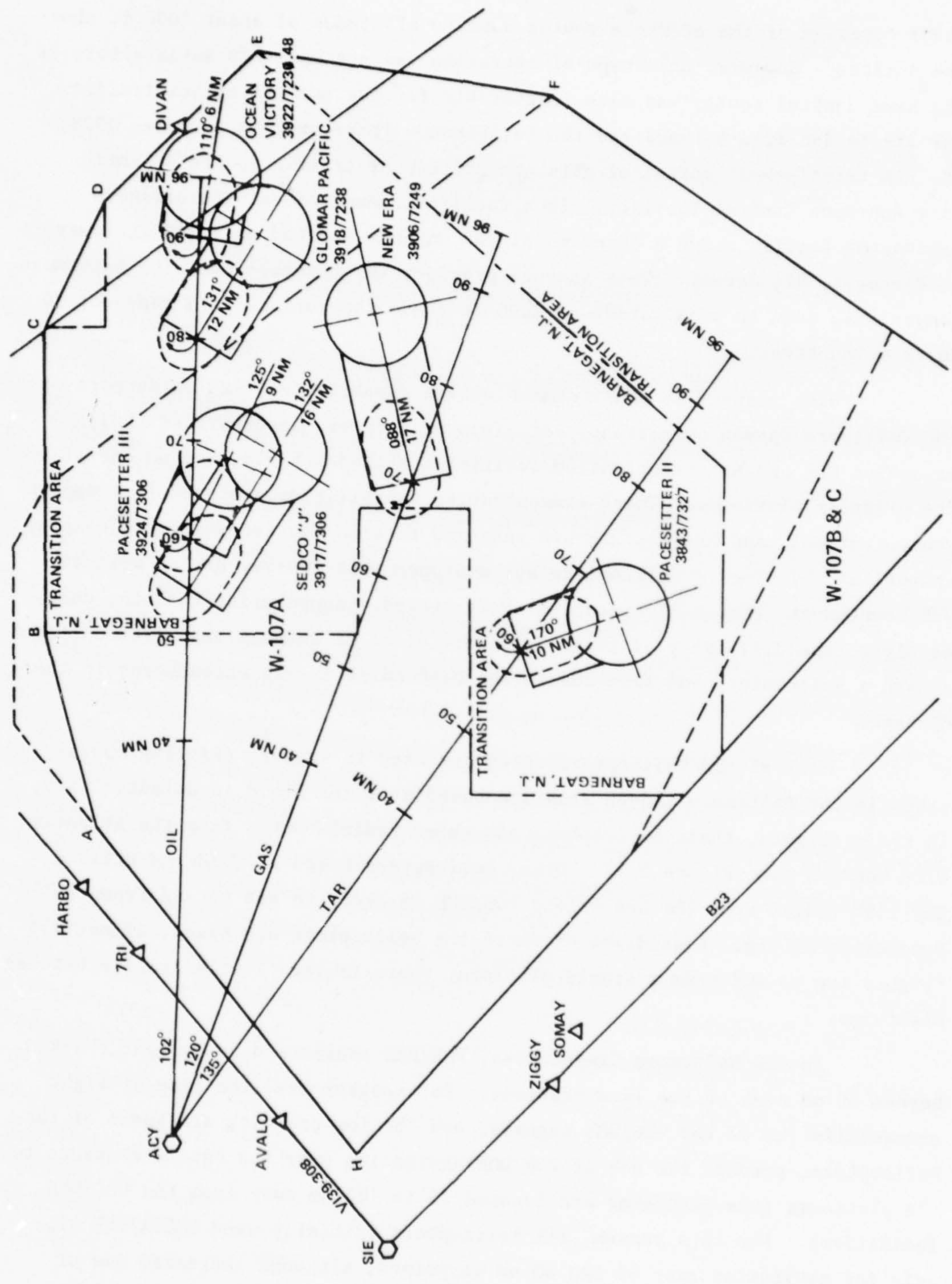
When Atlantic City IFR helicopter operations began in 1978, traffic on the offshore routes beyond 40 nm from the Atlantic City VOR was controlled by the New York Center. With its multi-radar network, the New York Center had

radar coverage of the offshore routes down to altitudes of about 2000 ft above the surface. However, this type of operation was not entirely satisfactory as the same control sector was also responsible for the control of jet traffic enroute to and from Bermuda and the Caribbean. Therefore, in December 1978, the FAA transferred control of offshore helicopter traffic to the Atlantic City Approach Control facility. This facility communicates with offshore helicopter traffic using a directional VHF antenna mounted on a 300 ft tower at Barnegat, New Jersey. This antenna provides VHF coverage over the Baltimore Canyon area down to an altitude of 2000 ft above the surface at a range of 80 nm from the tower.

With respect to other communication capabilities used in support of the Baltimore Canyon operations, Petroleum Helicopters Incorporated (PHI) maintains VHF and HF communication facilities at Bader Field, and on one of the offshore platforms. These communication capabilities are used for company communications, and helicopters are required to keep one receiver on a company channel at all times. Helicopters are equipped with two-way HF (as well as VHF) equipment, though HF operations have proved disappointing to date, due, partly to the difficulty of locating an efficient HF antenna installation aboard a helicopter; and also due to the high noise levels encountered in the HF band.

Most of the helicopters which are used to support drilling operations in the Baltimore Canyon area are based at Bader Field in Atlantic City; in their flights, these helicopters use three radial routes from the Atlantic City VOR/DME (see Figure 3.1). Other helicopters based at Wildwood utilize the 118° radial from the Sea Island VOR/DME in order to get to and from the Pacesetter II rig. Regardless of where the helicopters are based, almost all flights are to and from a single platform; there is very little traffic between platforms.

In the Baltimore Canyon area, VOR/DME routes are not flight checked beyond 40 nm east of the land stations. Put another way, the line-of-sight characteristics of the VOR/DME signals, and the low cruising altitudes of the helicopters, prevent the use of VOR/DME navigation over the entire distance to the platforms (the platforms are located 70 to 100 nm away from the VOR/DME facilities). For this reason, all helicopters initially used OMEGA/VLF signals for navigation east of the 40 nm waypoints, although increased use of LORAN C is anticipated.



ACY
SIE
HARBO
7RI
AVALO
ZIGGY
SOMAY
DIVAN
V139-308
B23
OIL
GAS
TAR
102°
120°
135°
A
B
C
D
E
F
H
W-107A
W-107B & C
TRANSITION AREA
BARNEGAT, N.J.
OCEAN VICTORY 3922/7238.48
GLOMAR PACIFIC 3918/7238
NEW ERA 3906/7249
PACESETTER III 3924/7306
SEDCO "J" 3917/7306
PACESETTER II 3843/7327
110° 6 NM
131° 12 NM
125° 9 NM
132° 16 NM
088° 17 NM
170° 10 NM
40 NM
96 NM

Figure 3.1

In some cases in the Gulf of Mexico area, non-directional beacons (NDB's) are used as homing aids for offshore platforms. Airborne radar (ARA) is used not only for weather avoidance but also as a backup navigation aid in homing toward, and determining the exact distance from, offshore platforms. A small transponder is sometimes used on the platform to show positive identification. Activated by the ARA pulses, it replies with two pulses, which show up on the ARA indicator as two strong blips directly behind the radar target and spaced 2, 4, 6, or 8 nm apart in range, as selected.

3.1.1 Single-Thread Description

Following is a single-thread description of a typical offshore flight from and to Bader Field. It is presented for the purpose of detailing the requirements for such a flight.

> A pilot must first check the weather, and then must call the Millville Flight Service Station to file a "canned" flight plan (see Figure 3.1.1) for the trip out and back. When he is ready to take off, the pilot calls Atlantic City Tower for his outbound clearance, and for clearance to depart Bader Field. Once in the air, he changes to departure control for any radar vectoring instructions which may be required to maintain separation from other traffic while he is climbing out and getting on course. During this time, the pilot is using VOR/DME navigation, and he has his VLF waypoints set up for his route of flight.
>
> Before reaching the 40 nm DME fix, the pilot is "handed off" to the offshore sector controller who is responsible for separating his flight from other traffic in this sector. As the helicopter will run out of radar coverage around the 60 nm DME point, the offshore controller must apply nonradar (procedural) separation standards for the remainder of the flight. The pilot is cleared to the destination platform via an assigned radial at an assigned cruising altitude. He is free to begin his descent as soon as he leaves the assigned radial (unless otherwise advised). Meanwhile, the pilot has an airborne radar turned on for use as a nonprecision approach aid. Generally, the pilot can detect his destination rig on the radar scope at a distance of 60 nm.
>
> The pilot now calls the platform for destination weather and for an altimeter setting before beginning his descent. He then sets up a descent path at a rate not to exceed 700 fpm.
>
> If the pilot is visually assured of landing before he loses VHF contact with the offshore sector controller, he cancels his IFR clearance with ATC. If he is already out of VHF contact with ATC when he finally sights the platform, or when he misses the approach, he calls the company radio operator on the rig in order to have this operator relay the appropriate message to the company shore station, and, eventually, to ATC.

GLOMAR 31

DEPARTMENT OF TRANSPORTATION—FEDERAL AVIATION ADMINISTRATION

FLIGHT PLAN

Form Approved
OMB No. 04-R0072

1. TYPE	2. AIRCRAFT IDENTIFICATION	3. AIRCRAFT TYPE/ SPECIAL EQUIPMENT	4. TRUE AIRSPEED	5. DEPARTURE POINT	6. DEPARTURE TIME PROPOSED (Z)	ACTUAL (Z)	7. CRUISING ALTITUDE
VFR / X IFR / DVFR	PHM 497	SA33/B	130 KTS	AIY			

8. ROUTE OF FLIGHT

ACY 102 OIL 080 N39 18 W 72 38

9. DESTINATION (Name of airport and city)	10. EST. TIME ENROUTE HOURS	MINUTES	11. REMARKS
Glomar Pacific N39 18.2 W72 38.4	0	45	

12. FUEL ON BOARD HOURS	MINUTES	13. ALTERNATE AIRPORT(S)	14. PILOT'S NAME, ADDRESS & TELEPHONE NUMBER & AIRCRAFT HOME BASE	15. NUMBER ABOARD
2	30	ACY	On file: Petroleum Helicopters Bader Field Atlantic City 609 3442967	On file PHI

16. COLOR OF AIRCRAFT: Yel/blk

CLOSE VFR FLIGHT PLAN WITH ________ FSS ON ARRIVAL

FAA Form 7233-1 (5-72) ☆ U.S. GOVERNMENT PRINTING OFFICE: 1976 - 671-621/561/7

GLOMAR 32

DEPARTMENT OF TRANSPORTATION—FEDERAL AVIATION ADMINISTRATION

FLIGHT PLAN

Form Approved
OMB No. 04-R0072

1. TYPE	2. AIRCRAFT IDENTIFICATION	3. AIRCRAFT TYPE/ SPECIAL EQUIPMENT	4. TRUE AIRSPEED	5. DEPARTURE POINT	6. DEPARTURE TIME PROPOSED (Z)	ACTUAL (Z)	7. CRUISING ALTITUDE
VFR / X IFR / DVFR	PHM 497	SA33/B	130 KTS	Glomar Pacific N 39 18.2 N 72 38.4			

8. ROUTE OF FLIGHT

N39 18 W72 38 OIL 080 ACY

9. DESTINATION (Name of airport and city)	10. EST. TIME ENROUTE HOURS	MINUTES	11. REMARKS
Bader Field AIY	0	45	

12. FUEL ON BOARD HOURS	MINUTES	13. ALTERNATE AIRPORT(S)	14. PILOT'S NAME, ADDRESS & TELEPHONE NUMBER & AIRCRAFT HOME BASE	15. NUMBER ABOARD
1	30	ACY	On file: Petroleum Helicopters Bader Field Atlantic City 609 3442967	On file PHI

16. COLOR OF AIRCRAFT: Yel/blk

CLOSE VFR FLIGHT PLAN WITH ________ FSS ON ARRIVAL

FAA Form 7233-1 (5-72) ☆ U.S. GOVERNMENT PRINTING OFFICE: 1976 - 671-621/561/7

Figure 3.1.1

If the expected stay on the platform will be short, the pilot can request a "through" clearance so that he can take off and climb on course on his return flight. If no "through" clearance or departure clearance has been received, and if the weather conditions permit, the pilot can take off, climb VFR into ATC communications coverage, and then request clearance for the return flight. If the climb cannot be made VFR, the pilot will have to request the return clearance before takeoff. At present, the request and the clearance must be relayed through company communication channels (this is a time consuming process). The initial clearance will be based on nonradar (procedural) separation standards.

During the return flight the pilot utilizes VLF or LORAN C for navigation in the offshore area, and contacts the offshore sector controller as soon as possible after takeoff to furnish his "off" time. As soon as the aircraft is back in radar contact, the controller will apply radar separation standards and vectoring instructions, as necessary, to provide position separation from other traffic. Near the 40 nm DME point, the aircraft will be handed off to the Atlantic City approach controller, who will continue to use radar procedures, and who will eventually clear the aircraft for approach if an instrument approach is necessary. The pilot obtains the Atlantic City Airport weather data from ATIS*, and he can supplement this with a call on a company frequency to obtain the weather data at Bader Field.

3.2 Operating Problems

As seen from the above, a basic ATC system problem which is associated with handling offshore helicopter traffic is that radar, VHF communications, and VHF navigation systems cannot provide the requisite level of surveillance, communication and navigation capabilities over the entire operations area. This situation is depicted graphically in Figure 3.2 using the Atlantic City-Baltimore Canyon area as an example.

Within Zone I, ATC radar surveillance is available to a range of about 60 nm, VHF communications are available to aircraft operating at altitudes above 1000 ft, and reliable VHF navigation coverage is available to 40 nm (approximate) at altitudes above 1000 ft.

Within Zone II, an aircraft would be outside the range of the Atlantic City radar, but it would still be within VHF communications coverage. Further, although radar control procedures could not be used here, procedural (nonradar) control would still be applicable within controlled airspace.

*Automatic Terminal Information Service (Recorded broadcast).

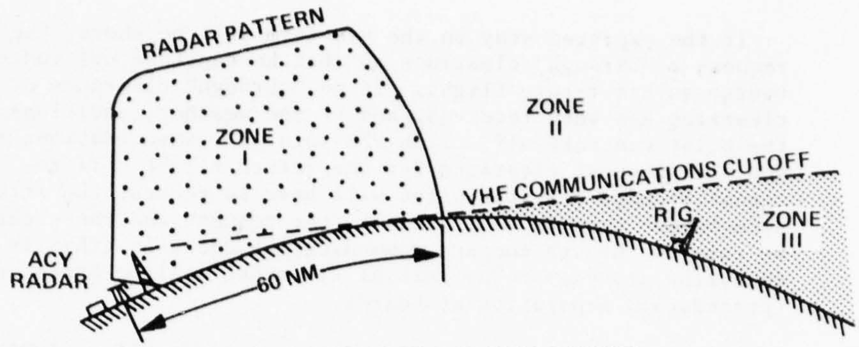


FIGURE 2.2.3B COVERAGE ZONES

ZONE / FUNCTION	I	II (OUTSIDE RADAR COVER)	III (OUTSIDE RADAR AND VHF COMMUNICATION COVER)
COMMUNICATIONS	VHF VOICE	VHF VOICE	VHF VOICE • VIA SATELLITE REPEATER • VIA BUOY REPEATERS • VIA AEROSTAT REPEATER VHF/HF VOICE • VIA REPEATER ON RIG AND RELAY ON SHORE • VIA REPEATER ON RIG W/ SELECTIVE CALLING • VIA RELAY ON RIG AND RELAY ON SHORE HF VOICE W/SELECTIVE CALLING VHF/UHF VOICE VIA REPEATER ON RIG AND TROPOSCATTER
SEPARATION ASSURANCE	PRIMARY AND SECONDARY RADAR	VHF DATA LINK • VIA SATELLITE REPEATER • VIA METEOR BURST • VIA AEROSTAT REPEATER HF DATA LINK PROCEDURAL CONTROL	VHF DATA LINK • VIA SATELLITE REPEATER • VIA METEOR BURST • VIA AEROSTAT HF DATA LINK • POSSIBLY COMBINED WITH OCADS PROCEDURAL CONTROL CDTI PLUS A/A VHF

Table 3.2 Offshore Communications and Surveillance Options

Within Zone III, an aircraft would be outside radar and VHF communications coverage. Unless another means of communication with ATC is available, only one IFR aircraft at a time would be allowed in any given area.

3.3 Technical Alternatives

3.3.1 Navigation

Figure 3.2 does not depict navigation coverage. Although VOR/DME is subject to line-of-sight cutoff characteristics, several navigation systems are available to provide complete coverage throughout all of the airspace shown. The FAA is now conducting tests of LORAN C, a low-frequency (LF) system with coverage down to the earth's surface. Preliminary tests of LORAN C indicate that the accuracy of LORAN C in the Atlantic City area is somewhat better than that of OMEGA; and so, it can be expected that the use of LORAN C will increase in this area.

Another navigation aid which could be used in the OTH environment is the LF non-directional beacon (NDB). A pilot of a helicopter fitted with an automatic direction finder (ADF) receiver could utilize a NDB on an offshore drilling platform to determine the bearing to the platform and station passage when making an instrument approach to the platform.

A candidate system for precise navigation anywhere on the globe is the global positioning system (GPS) which has been developed, and is now being implemented, by the Department of Defense. The total system, which will use 24 satellites in a suite of selected orbits, is still several years away from completion. Although the prices of the necessary avionics are presently forecast to be very high in relation to equipment for other systems mentioned above, the potential system accuracy is much greater. One possible operational disadvantage of GPS (though not considered major) is that it probably will require several minutes of warm-up time to obtain "lock-on" before the airborne equipment is ready for use. During the years before the GPS is ready for civil use, however, it is expected that technology will continue to advance rapidly. Therefore, it may be possible that technological breakthroughs (such as mass production of an advanced system employing VLSI circuitry) will alleviate this disadvantage.

3.3.2 Communications

A number of relatively sophisticated systems have been considered as candidates for satisfying helicopter OTH and surveillance communications needs. Among the types of systems examined were troposcatter, meteor burst, buoy, and satellite. These systems are not considered applicable for further investigation at this time for the reasons given below.

a. Troposcatter:

- o Excessive electrical power requirements for helicopters*

b. Meteor Burst:

- o Lengthy time lags between successive meteor scatter bursts
- o Development of an acceptable helicopter antenna required

c. Buoy Repeaters (VHF):

- o High cost of installation
- o High power requirement for long periods of unattended operation
- o Possible shadowing by high seas

d. Satellite:

- o High unit costs of satellite systems and equipment
- o Helicopter-related complications in antenna size, location, and pointing
- o Helicopter rotor/transceiver coordination development required.

Atmospheric and man-made noises makes HF communication fatiguing. Thus, if HF is used, it may be necessary to use selective calling with all equipments,

---

*Note that troposcatter links may find application under conditions where helicoper ATC communications can be effected through the use of a VHF link to an oil or gas platform, and thence, to shore (and vice versa) by means of a so-called "tropo" link. The expenditure of funds to support an operation of this type is based, at the least, on the assumption that a sufficient density of offshore platforms exists in a given area as to make economical the use of such a link, and of such a centralized HF repeater capability. Typical areas where tropo/VHF repearter links may find application include, but are not limited to, the Gulf of Mexico and the North Sea.

Table 3.3.2 Approximate VHF Range in Nautical Miles

SHORE ANTENNA HEIGHT IN FEET	AIRCRAFT HEIGHT IN FEET					
	ON RIG 100'	1000	2000	3000	4000	5000
100	25	51	67	80	90	99
300	34	60	76	89	99	108
500	40	66	82	95	105	114
1000	51	78	94	106	117	126
2000	67	94	110	122	133	142

in order to avoid the need to maintain a continuous listening watch on the channel. Such systems would require a coder/decoder on each air and ground system in order to provide the selective calling feature; given today's solid-state and large-scale-integrated (LSI) circuit technology, however, this is not a problem.

The need for continuous static-free voice communications between controllers and pilots has led to a long-established FAA policy of using only VHF and UHF channels for air/ground communications. Table 3.3.2 shows the approximate VHF/UHF communication ranges based on various combinations of antenna height and aircraft altitude over water. To relate this table to areas of current operations, note that at this time, the offshore drilling platforms in the Gulf of Mexico area are located between 50 to 130 nm offshore, while in the New Jersey area, they are located between 70 to 100 nm offshore. Obviously, communications coverage in the OTH environment is a primary requirement which must be addressed by the FAA at the earliest possible time.

3.3.3 Surveillance

The lack of surveillance radar coverage over a major portion of helicopter routes (altitudes from 100 to 5000 ft, and distance from shore of up to about 150 nm) initially requires the use of nonradar control procedures.

One way of obtaining low-altitude surveillance of offshore areas over the horizon from shore facilities would be to mount an SSR interrogator-reply (I-R) unit and antenna on an offshore platform, to obtain SSR position/identify/altitude data from helicopters in the vicinity. This data would be remoted to the ATC shore facility via a suitable channel.

A longer-term solution for OTH surveillance over a much larger geographical area would be to develop an air/ground data link for the automatic reporting of aircraft position and altitude. Such a unit would store the latest position data from the aircraft navigation receiver and the latest altitude data from the aircraft altimeter transducer. When interrogated on a roll-call basis from the ground station, it would transmit the stored data to the ATC facility. Here a computer would process the data and display a "synthetic radar" tagged target on the PPI. HF channels would be used for the interrogation and replay, unless suitable VHF links were available.

This concept has potential application not only for offshore helicopters, but for other traffic in remote areas and in the oceanic airspace.

The concept of distributed management responsibilities in the ATC system is another potential solution to the control problem. Distributed management refers to the selective allocation of certain control functions to the pilot of the aircraft (e.g., aircraft separation or collision avoidance by means of onboard proximity warning indicator devices). The concept of distributed management responsibility in the ATC system offers potential improvement over the sole use of nonradar control procedures in the offshore environment mentioned above. This concept should be considered for research, test and implementation in the ATC system.

Figure 3.3 shows the concept of a low-altitude route structure which may have future application in certain areas of high-density VTOL traffic (such as around offshore platforms). This low-conflict, two-level VTOL grid concept eliminates traffic conflictions caused by opposite-direction or crossing traffic. Under this concept, a number of alternating, one-way primary routes are spaced at least 4 nm apart. All primary routes are at the same altitude. These routes are crossed by a number of alternating one-way routes, also spaced at least 4 nm apart but at an adjacent altitude level. All routes are based on some form of area navigation, and are coded on the chart for easy reference.

3.4 Conclusions and Recommendations

Based on accuracy, availability, and reliability, LORAN C and OMEGA appear to be the most logical choices for offshore navigation during the near term. The future use of GPS for this purpose will depend on system implementation progress, as well as the development of affordable GPS avionics.

ATC communications are often time-critical; it is important that they be completed without repeats or delays. Therefore, VHF is preferable to HF for operational reasons; it is not subject to interruption by atmospheric static or by diurnal skip effects.

In providing OTH communication between ATC facilities and offshore helicopters, it appears preferable to establish remote VHF transmission and reception facilities on offshore platforms, for line-of-sight communications

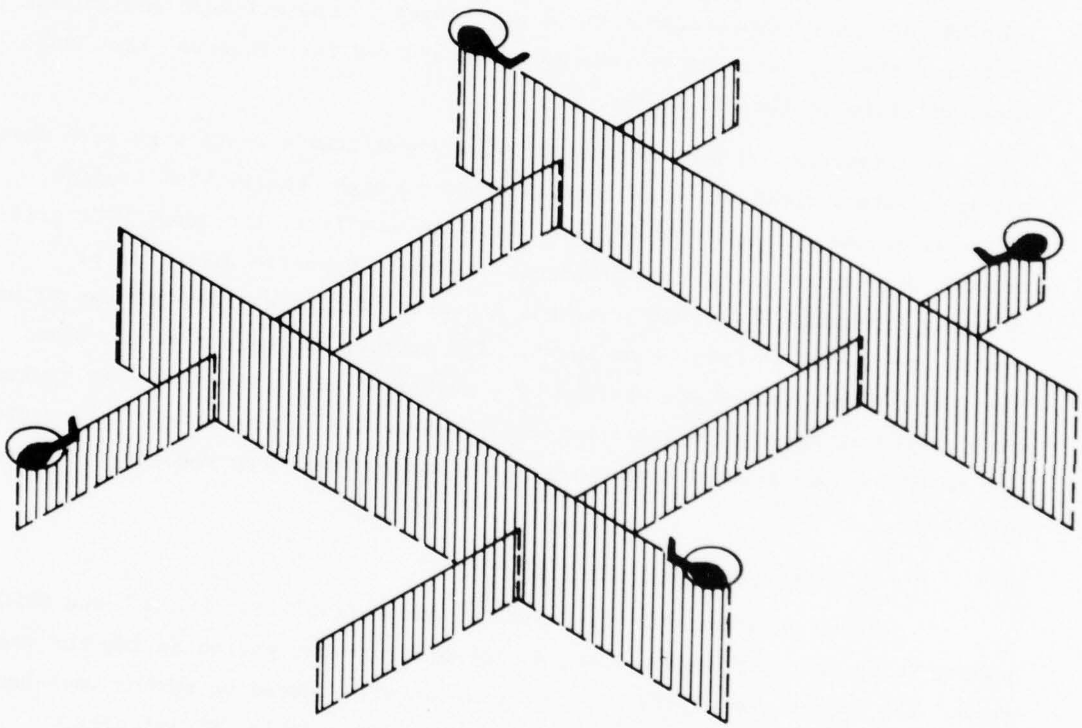


Figure 3.3 Concept of Alternating Opposite-Direction Routes at Same Altitude: Crossed by Alternating Opposite-Direction Routes at Adjacent Altitude

site with the ATC facility. Depending on the availability of platforms at intermediate locations, within line of sight of each other, the following alternatives appear most preferable:

Microwave relays
Underwater cable
VHF Troposcatter
Satellite repeater

The choice, in any case, would depend upon economic, as well as technical considerations.

It is expected to be a considerable time before offshore traffic density will justify the use of any type of surveillance system. When this occurs, consideration should be given to the practicality of installing remote secondary radars, connected to the ATC facility via wide-band or narrow-band links.

Meanwhile, as a possible long-term solution to the offshore helicopter (and also the oceanic ATC) surveillance problem, consideration should be given to the development of an HF data link, in which airborne equipment sends lat/long data from the navigation system, and altitude data from the altimeter transducer, automatically in response to interrogations received from the ATC facility. A computer at the ATC facility processes these replies, and generates alphanumerically-tagged targets at the appropriate positions on the ATC radar display.

For low density operations in Zone III, it might be practical and economical to establish one-way routes together with air-to-air communications; here, the traffic flow in each locality would initially be organized by ATC, but the pilots themselves would monitor their own separation.

For some offshore areas, it may be desirable to implement a distributed management system in which air-to-air communications would be augmented by means of a proximity warning device or cockpit display of traffic information (CDTI). The airborne equipment should be capable of detecting other aircraft while outside of normal radar/SSR range.

Regardless of whether a distributed management system is ever developed, the relatively uncluttered and uncomplicated Atlantic City offshore

environment, plus the proximity of NAFEC, makes the Atlantic City helicopter operation an ideal test bed for the FAA to try out an HF data link position reporting system (and various other forms of cockpit traffic indicators, as well).

4.0 REMOTE AREA OPERATIONS

4.1 Description

Helicopters are used to perform many tasks, many of which are related to urban use. However, there are many other functions which are performed routinely by helicopter, and which do not get the attention of the daily news media because of the relatively remote areas in which the work is accomplished.

In March 1978, the Helicopter Association of America published "The Helicopter: Its Importance to Commerce and to the Public," which included a list of current helicopter uses. Extracted from that list are tasks which are considered "remote area" operations. These operations include, but are not necessarily limited to:

> Aerial recovery, aerial survey, agriculture, cargo transport, conservation, exploration for natural resources, firefighting, fish life studies, forestry patrol, frogmen delivery, game management, geological survey, herding cattle and stock, hydro-electric surveys, ice-breaking patrol, lighthouse support, logging, mapping, mineral exploration, missile support, ocean salvage, offshore transportation, oil drilling and surveying, patrol of powerline cables and pipelines, pipeline construction, poaching surveillance, prospecting, ranching, railway patrol, right of way spraying, snow removal, snooding (oil spill containment), stringing wire and cable, wildlife surveys and preservation.

The HAA document cited above also notes that new uses for the helicopter are constantly being developed; further, it makes no claim that the current list of uses specifically covers all on-going applications. The helicopter is so flexible in application that it would be difficult, if not impossible, to maintain an absolutely current list of all the specific tasks it is performing.

A typical remote area operation in the Appalachian Mountains, for example, involves a company-owned helicopter which is based at a medium-hub airport, and which is used to transport management personnel and machinery parts to and between a number of company-owned coal mines. Although nearly

all of the flights are made under VFR or SIFR, there is an occasional need in the Appalachian area to climb through or above cloud layers in order to cross a mountain ridge before descending on the other side. Beyond the terminal area, many of these flights would not be visible on ATC radar except during the time that they were above the mountain ridges. The destination, usually a private heliport, may have no navigation or approach aids, in which case the approach to landing would have to be made under VFR. The flight day may involve additional flights between other private heliports and finally return to the base, probably at a medium hub airport.

4.2 Problems

During the initial phase of this study, it was not possible to address the problems of remote area operations in the same degree of detail as intercity or offshore operations. It is possible that the additional effort planned for the next phase of the program will uncover additional problems besides those which are described below.

The operational problems associated with IFR helicopter flight in remote areas are similar in some respects to those in offshore areas, in that the helicopters often will be flying beyond the coverage of ATC communications, VOR/DME navigation, and ATC radar. Also, many remote area operations will originate or terminate at a large airport where they will have to be interleaved with fixed-wing operations.

The previously described need for controller familiarization with helicopter capabilities and limitations, and for refresher training in nonradar control procedures, has been particularly evident in connection with remote area operations.

An additional problem characteristic of remote areas is the lack of weather reporting stations.

Another problem is that low-altitude military routes are deliberately located in remote areas in order to avoid populated areas. These routes are used only in VMC (Visual Meteorological Conditions), but involve high speed cross-country tactical training flights at extremely low altitudes. Although the locations of the low altitude military training routes are shown in the Airman's Information Manual, and the hours of active operation are made

known to ATC, a more positive means of distributing this information, particularly to VFR pilots in remote areas, is needed.

4.3 Technical Alternatives

Some of the same technical solutions previously recommended in this report, for providing OTH surveillance, navigation, and communications, and for providing a means of showing random waypoints on the scopes, are equally applicable to remote area operations. The provision of additional weather reporting stations is an economic rather than a technical problem; however, the development of automatic remote weather reporting stations may provide at least a partial solution.

4.4 Conclusions and Recommendations

The provision of dependable static-free VHF communications at helicopter operating altitudes is a primary need in remote areas, it is in other parts of the system. Additional RCAG (Remote Communications Air/Ground) facilities, using land lines or microwave links to the appropriate ATC facility, may be the most feasible solution to this problem. The use of procedural control is initially the most feasible method of providing separation between aircraft in remote areas having very low IFR traffic density.

Refresher training in procedural control is recommended for ATC personnel in order to exploit every possible means of moving traffic safely and expeditiously in areas outside of radar cover. This training should be combined with the previously described familiarization training in helicopter characteristics and limitations, and in the area navigation procedures used by helicopters.

As helicopter traffic grows in remote areas, additional ATC functions such as surveillance may become economically justifiable, in which case the FAA will have cause to institute those changes necessary to provide appropriate ATC support. Therefore, it is recommended that the FAA periodically monitor the volume and types of remote area operations in order to be prepared to initiate appropriate action in support of these operations. Associations of remote area operators must also monitor their own needs, and periodically report them to the HAA, to ensure FAA awareness.

One method of reducing the collision hazard between civil aircraft and military aircraft operating on established low level routes in remote areas would be for the FAA to establish one or more "800" (toll-free) long-distance telephone numbers which could be used by any pilot to obtain an automatic recording of the current activity status of specific low level routes.

5.0 FUTURE HELICOPTERS AND OTHER TYPES OF VTOL AIRCRAFT

5.1 General

Continued increases in helicopter usage will depend upon such factors as the decentralization of the population and on the availability of fuel. Those communities that have adopted an enlightened attitude toward VTOL aircraft will benefit from the use of helicopters. Evolving transportation requirements in urban, suburban and remote or developing areas will shape the technology of the next generation of helicopters. Some analyses of the growth in helicopter numbers and in forecast flight hours, for example, indicate a potential three-fold increase in urban operations by 1985. This optimistic projection of helicopter growth, however, must be tempered by a realization of those problems which are related to public acceptance of VTOL aircraft, and to the strong research, development, and maintenance base required for these aircraft. Brief reviews of these problem areas follow, and are intended to highlight how they may affect the expanding growth of the helicopter industry and the development of advanced technology for use in future helicopters.

5.2 Public Acceptance

Reasonable effective mass-transportation systems have been developed in the past to operate within the restricted dimensions of metropolitan areas (e.g., light rail transit (LRT), bus and subway systems, etc.). The most effective solution will probably be the development of an integrated system involving elements of surface and air transportation. In such an integrated transportation system, short-haul VTOL aircraft will probably play a vital role. Two major problem areas must be solved before these aircraft can be successful: design criteria and heliport development.

To gain public acceptance, future helicopters and other VTOL aircraft must meet the following criteria:

(a) They must offer convenience and comfort that is equal to, or greater than, that offered by other means of transportation.

(b) The safety of the aircraft must be equal to, or greater than, that of alternative modes. Since ultra-short-haul aircraft will make an unusually large number of takeoffs and landings (sometimes under conditions of bad weather and limited visibility, and in close proximity to highly-populated

areas), the matter of flight safety obviously merits attention. This implies that the aircraft must be inherently stable in all modes of flight, and that it must be thoroughly tolerant of engine failure.

(c) The operating cost of air transportation must be competitive with alternate transportation modes.

(d) The aircraft must be reliable, and must have all-weather capabilities to meet the requirements of scheduled transport operations.

(e) The aircraft must be quiet so that it does not add significantly to the ambient noise level of the surrounding areas. It must have no peculiar or unacceptable noise signatures.

5.3 Heliport Development

Although the helicopter industry has enjoyed considerable growth in the past ten years, executive transport operations have been limited by public resistance to helicopter operations which has been brought about by concerns related to safety and noise. These concerns have slowed the growth of public-use heliports within urban and suburban centers.

Both the urban decentralization process and the needs of the executive transport sector argue favorably for the establishment of a wide-spread network of public-use heliports. Although there are more than 3,400 heliports in the United States, Canada and Puerto Rico, less than 500 are public-use facilities, and fewer still are equipped for IFR operations.

Experiments in urban operations in corporate transportation, banking, firefighting, law enforcement and emergency medical rescue has proven that helicopter service expands when heliports and service facilities are made available. Without the growth of public-use heliports, service to the public cannot expand and, consequently, the growth of the helicopter industry may be slowed. While noise and safety are primary factors to consider in heliport development, there are other factors involved. Location, public use versus private use, obstruction clearances, availability of charts and plates, zoning restrictions, and regulation are just a few of these factors.

Mr. John E. Meehan, Heliport Manager for Pan American World Airways (60th Street Metroport, New York), has stated:

"Helicopter sales will not continue to grow unless the helicopter has some place to land. If you have no access to urban centers, corporate business centers or trade centers, you will find that the sales will diminish and will be relegated to those special-use applications of the helicopter."

5.4 Maintenance

The helicopter requires a much higher level of maintenance per flight hour than does a fixed-wing aircraft of similar size; this is because of mechanical complexity and high vibration levels.

Most of the present force of helicopter mechanics were trained by the Army. However, with the end of the Viet Nam conflict, the Army's helicopter maintenance training program was greatly reduced. As a result, by 1978, the supply of newly-trained helicopter mechanics available to the industry was insufficient to replace those leaving.

Unless measures are taken to overcome this problem, a shortage of trained helicopter mechanics could limit the growth of the industry. It should be noted, too, that it takes 6 to 18 months of training to produce a qualified helicopter mechanic; thus, even if steps were taken immediately to effect a comprehensive training program, there would be a shortfall of capable mechanics in the near-term.

5.5 Research and Development

Because of the extremely high costs incurred in the design and development of helicopters and their support avionics, most helicopters found in the civilian community use adaptations of military airframes, systems and equipments. It may be anticipated, though, that future helicopter systems for civilian use will materialize to meet other market requirements in a more direct manner. Unfortunately, lead times for the development, test, and implementation of advanced avionics can reach, or exceed, twenty years. Thus, there is a strong need to establish immediately a commercial helicopter research and development (R&D) program (rather than to look for "spin-offs" from military R&D programs) in order to support the development and application of IFR all-weather helicopter/VTOL operations. If the helicopter is ever going to realize its full potential, it must be designed to provide the commercial user

with services at any time and in any place; in short, it must be competitive with other modes of transportation.

In addition to the need for advanced IFR avionics, immediate R&D needs exist in the areas of vibration and noise reduction, instrumentation (especially instrumentation which will provide an all-weather capability), pilot workload reduction, and, generally, in areas leading to higher performance, reliability, and efficiency.

Work in other areas, as well, will contribute to the expansion of helicopter utilization; these include development of flight procedures, faster dissemination of weather data, more accurate weather forecasting, and the development of heliports and associated landing aids.

Some investigations have already resulted in significant refinements in equipment which provides IFR capabilities. For example, autopilots coupled to area navigation equipment can provide single-pilot, hands-off flying. However, additional work is required to make the helicopter an efficient, cost-effective and viable means of transportation.

5.6 General Outlook

It is highly probable that the basic helicopter technology used today will characterize the helicopter in the year 2000. Although significant improvements can be expected in such areas as avionics, flight controls, engines, structural materials, rotor heads and blades, the helicopter's flight characteristics will not change to the degree that present ATC requirements will be significantly affected. This assertion, however, is premised on the condition that the changes necessary to permit helicopters to operate efficiently are effected by FAA. The greater speed and comfort offered the "new generation" helicopters (such as the Sikorsky S-76, the Bell 222 and some aircraft of European design) will create new vistas for the travel and business communities, and IFR utility will generate demands for helicopter air traffic service which will dwarf the demands made today.

As new technology overcomes many of the helicopter's technical limitations vibration, the utility of the helicopter will be greatly expanded. Assuming that public acceptance can be achieved, the progress of helicopter development can be broken down into two phases: short-term (to 1985) and long-term (beyond 1985).

5.6.1 Short-Term

"New generation" helicopters are expected to satisfy most of the corporate and offshore requirements through 1985. These helicopters are typically 150 knot, 10,000 lb aircraft with ranges up to 300 nm. In some instances, they have proven more efficient (i.e., shorter terminal-to-terminal times) than have conventional airplanes for trips up to 200 nm.

In the near-term, anti-icing and de-icing equipment will be employed despite the expected loss in lift capability due to weight and power requirements for their operation. Larger helicopters, such as the civil version of the Boeing/Vertol Chinook, will be used in offshore opeations, where their greater range will be necessary to support drilling operations as far as 300 nm from land. For example, the Chinook has already been ordered for North Sea operations. It will carry 44 passengers and will have an optimum altitude of 10,000 ft above sea level.

Further advances in helicopter flight capabilities during the next few years will be in the form of refinements which will lead to reduced noise and vibrations at the same time, and to reduction in pilot workload (through the use of advanced avionics and instrumentation). Autopilots and automatic navigation and approach aids will make lower landing minimums possible.

5.6.2 Long-Term

Advances in helicopter technology will enhance and extend the helicopter's flight characteristics and capabilities. Changes that do occur, however, will probably come slowly, because of the very long lead times required to develop new designs, and also because the high investment in currently-used helicopters will require prolongation of their useful life. Advances in helicopter design which are anticipated, and which will affect the air traffic control system, are:

(a) Speed. Research with compound helicopters (i.e., helicopters which use rotors for lift, and have stub wings and separate engines for forward flight) indicates that speeds of up to 220 knots are feasible.

(b) Range. About half of today's airline passengers make trips of 500 nm or less, well within the range of advanced helicopters. With a cruising speed of 300 knots, this could make post-1985 helicopters viable alternatives

to short-haul airlines and ground transportation if convenient heliports are established for passengers.

(c) Altitude. The icing problem, one factor which limits the utility of today's helicopters, will be almost completely eliminated, thereby making the helicopter a virtually all-weather aircraft. Efficiency at altitudes will be increased through advancements in engine and rotor design, and, possibly, by the use of stub wings. The requirement for pressurization has been a matter of continuing interest in the helicopter industry. It is generally felt, however, that the need for flight above 10,000 feet will be minimal except in mountainous areas.

(d) Avionics. Advances in avionics will continue to make the pilot's workload easier, and will provide greater flexibility in route selection. Such improvements, coupled with precision landing aids specifically tailored for helicopter operations, might justify the lowering of destination and alternate weather minima. It is also anticipated that new electronic equipment such as DABS/ATARS will make the positive control of helicopters simpler and safer within SSR coverage areas.

5.7 Wide-Body Helicopters for Relief of Airport Congestion

The FAA now estimates that the costs of aircraft delays in the USA are approaching one billion dollars per year, with several airports running at full capacity. Hourly quota systems are presently in effect at four major airports; it is almost certain that the FAA will institute quota systems at a number of other major airports within the near future. If this occurs on a large scale, the airline industry could be faced with a zero-growth situation due to the lack of additional landing slots at major terminals.

But helicopters do not need airports. If commercially viable short-haul helicopters could be produced and if close-in heliports could be established near city centers, airlines could transfer a portion of their short-haul operation to helicopters, thereby releasing numerous airport landing slots for more remunerative long-haul wide-body jet flights. Meanwhile, short-haul passengers would be given faster city-center to city-center service than they get today.

This concept is already under active consideration by British Airways, who propose the use of 200-passenger Boeing/Vertol wide-body helicopters for some of their London-Paris schedules, operating between metropolitan heliports

and thereby releasing an equivalent number of landing slots at Heathrow Airport, for wide-body intercontinental jets.

Another advantage of this concept is that it enables the huge capital investment in airport runways to be used more productively.

5.8 Other Types of VTOL Aircraft

Major obstacles to the adoption of other types of VTOL aircraft used for commercial purposes are related to social and environmental acceptance.

For example, the lift-fan and jet-lift types of VTOL's have relatively small disc area, with correspondingly higher disc loading, than the helicopter. As a result, the higher velocity slipstream of the lift-fan and jet-lift VTOL's makes them correspondingly more noisy. Although tile-wing VTOL's have somewhat lower disc loadings, they are mechanically very complex.

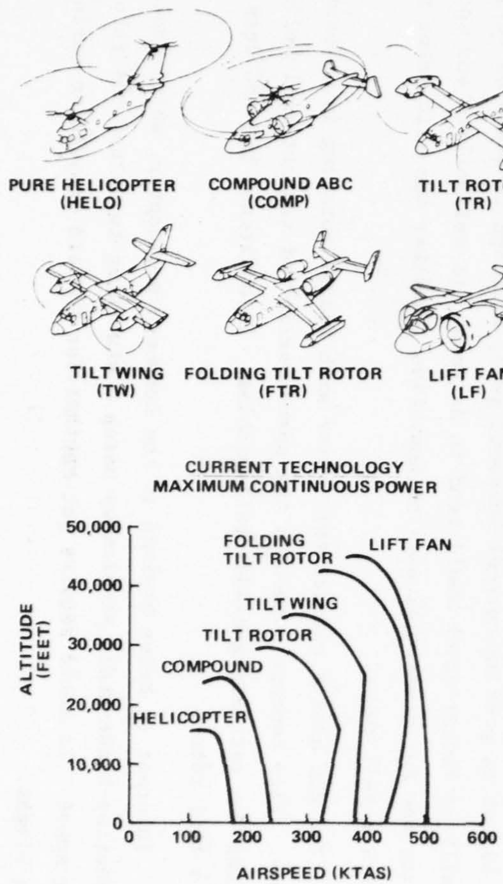
Constraints on noise are expected to rule out the use of jet-lift types of VTOL's in congested urban areas during the forseeable future. This leaves the tilt rotor, the ABC (Advancing Blade Concept) helicopter and the compound helicopter as the prime candidates for development.

The tilt rotor helicopter may develop ultimately into a jet-powered compound helicopter with blades which retract into wingtip nacelles. This type, called the folding tilt rotor (FTR) aircraft, could have speed and altitude performance almost as good as current subsonic jets, although it would be very complex mechanically--a factor which would tend to decrease its reliability and thus discourage its use for commercial airline operation. Neither the tilt rotor nor the FTR require a tail rotor.

The ABC uses a coaxial twin rotor with blades rotating in opposite directions. This concept surmounts the speed barrier of conventional helicopters by avoiding the retreating-blade-stall problem. In addition, the ABC does not require a tail rotor.

Interest is being revived in the compound helicopter, which avoids the retreating-blade-stall problem by using a stub wing to unload the rotor at cruising speed. It would require jet engines for forward propulsion during cruising flight.

Boeing/Vertol recently completed a study comparing six types of vertical lift aircraft, as applied to hypothetical Navy and Marine Corps missions; Figure 5 contains excerpts from this study.



The following geometric constraints were placed on the aircraft:

Helicopter: 8-psf disc loading – Provides acceptable speed capability without severely compromising size; retains good autorotative capability.

Compound: 15-psf disc loading – Matches power to speed capability in the mid-200-knot area.

Tilt Rotor and Folding Tilt Rotor: 35-foot rotor diameter, 100-psf wing loading – The diameter restriction is required for shipboard compatability, and the wing loading constraint provides acceptable transition corridor width.

Tilt Wing: 55-psf disc loading; 0.43 wing chord to prop diameter (C/D) ratio – The wing loading was selected to obtain minimum aircraft size; the C/D restriction provides acceptable wing stall boundaries during transition.

Lift Fan: 1.2 fan pressure ratio, 140-psf wing loading – The pressure ratio provides minimum weight while the wing loading gives acceptable STOL and transition performance for this concept which has significant induced lift from flap blowing.

Figure 5 Comparisons of Six VTOL Configurations--From Boeing/Vertol Study

6.0 SUMMARY OF RECOMMENDATIONS

6.1 Background

This section summarizes the recommendations presented in Sections 2, 3, and 4 of this report. Recommendations have been categorized as short-term or long-term (implementation before or after 1985, respectively). Some of the recommendations resulting from this study have already been placed in effect prior to the publication of this report. Several recommendations apply to more than one of the three regimes studied. Table 6.1 shows their application to intercity, offshore, and remote areas.

6.2 Short-Term Recommendations

6.2.1 Charting

It is recommended that the FAA determine the most effective methods of depicting helicopter corridor and waypoint data on Radio Facility Charts, and on Sectional and Local Aeronautical Charts. Further, when helicopter corridors are opened to the public, data for these corridors should be printed on the charts mentioned above rather than confining the data to a separate helicopter chart.

6.2.2 Dual Routes for Baltimore Canyon

It is recommended that helicopter routes 4 nm north of, and parallel to the OIL route, and 4 nm south of, and parallel to the TAR route, be established in the Baltimore Canyon area. These routes should be established to handle two-way OTH IFR traffic when icing conditions or Navy operations do not permit conventional altitude separation of two-way traffic on these routes.

6.2.3 Terminal Instrument Procedures (TERPS) Revision

It is recommended that high priority be given to the development and verification of appropriate approach criteria and weather minima for helicopters; these approach criteria and weather minima must take cognizance of the flight characteristics of current types of helicopters.

6.2.4 Standard Terminal Arrival Routes (STARs)

It is recommended that criteria for the establishment of STARs be established, with due consideration given to helicopter flight characteristics

TABLE 6.1 SUMMARY OF RECOMMENDATIONS

Reference Paragraph 6.2 --	Subject of Recommendation	Application			FAA R&D Reqd.
		Inter-City	Off-Shore	Remote Areas	
1	Charting	•			
2	Dual routes for Baltimore Canyon		•		
3	TERPS revision	•	•	•	
4	STARS	•			
5	Missed approach waypoints	•	•	•	
6	A/A communications		•	•	
7	NEC authorization	•			
8	Radar separation criteria	•			
9	SIDS	•			
10	Familiarization training	•	•	•	
11	Refresher training - non-radar contl.		•	•	
12	MLS training	•			
13	Reduction of MDA		•		
14	Dual-waypoint holding pattern	•	•		•
15	Random route display	•	•	•	•
16	Low-altitude military routes		•	•	
17	Low-altitude VTOL route concept	•	•	•	•
18	Propagation		•	•	•
19	Navigation equipment checks	•	•	•	
20	Approach metering	•			
21	OTH communications		•	•	•
22	OTH separation assurance		•	•	•
23	NAVSTAR/GPS	•	•	•	

and to the need to maintain helicopter routes as independent of fixed-wing routes as is possible.

6.2.5 Missed Approach Waypoints

It is recommended that the missed approach waypoint for a point-in-space approach be located near a prominent visual landmark wherever possible. This is especially desirable for approaches which terminate over water.

6.2.6 Air-to-Air (A/A) Communications

It is recommended that appropriate use of A/A radio communications capabilities be made to expedite offshore helicopter traffic, when at least one of the aircraft involved is beyond ATC communications coverage. It is further recommended that this procedure be discontinued as soon as a more suitable direct controller-offshore helicopter communications path is implemented.

6.2.7 NEC Authorization

It is recommended that priority efforts be made to simplify and standardize the requirements for authorizing pilots and helicopters to use the NEC.

6.2.8 Radar Separation Criteria

It is recommended that ATC Handbook 7110.65.A be revised to permit the use of 2 nm separation between helicopters operating at airspeeds below 90 knots within terminal areas.

6.2.9 Standard Instrument Departure Procedures (SIDs)

It is recommended that criteria for SIDs for helicopters be established with due consideration for helicopter flight characteristics and with the routes being established from the point of takeoff (heliport or airport). In order to simplify ATC communications, it is recommended that departure routes which will be most heavily used by helicopters be considered potential candidates for SIDs based on the criteria set forth in FAA Order 7100.8. Consideration should be given to the cautionary notes which are a part of the Order. This Order should be reviewed to resolve the complexities of charting.

6.2.10 Familarization Training

It is recommended that the FAA initiate a basic course in helicopter characteristics and limitations, helicopter navigation, and precautionary methods to be taken to avoid helicopter downwash damage to other aircraft. It is recommended that this course be administered to new ATC students at the FAA Academy, and that the course material be combined with training in local procedures administered at the facility level. It is further recommended that the FAA establish a program to familiarize controllers and helicopter pilots with each other's environment.

6.2.11 MLS Training

It is recommended that the FAA develop and test MLS approach procedures, in which helicopter traffic on short curved approach paths is interleaved with conventional fixed-wing approaches. The lessons learned from this activity can be incorporated in training programs for controllers at any sites at which MLS is installed.

6.2.12 Refresher Training - Nonradar Control

It is recommended that FAA facilities handling OTH IFR helicopter traffic include in their training programs the techniques of procedural control for use with helicopters operating outside radar surveillance coverage.

6.2.13 Reduction of MDA for Offshore Helicopter ARA Approaches

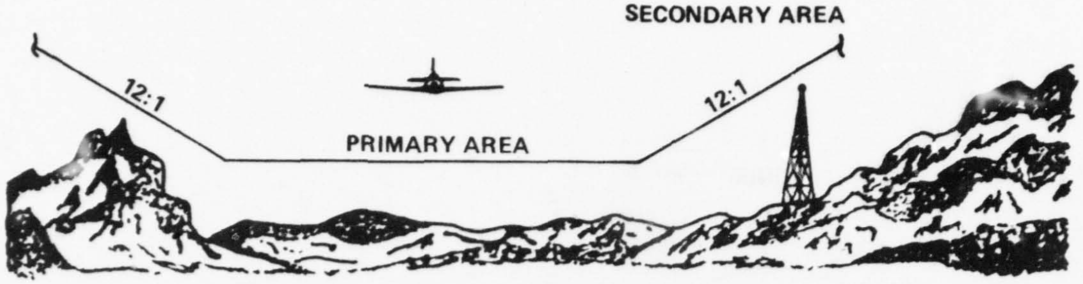
It is recommended that the concept illustrated in Figure 6.2.13A and 6.2.13B be tested to determine its application in making possible a reduction in MDA for offshore helicopter ARA approaches.

6.2.14 Dual-Waypoint Holding Pattern

It is recommended that the use of a dual-waypoint holding pattern be tested in flight simulation as a means of safely reducing holding airspace dimensions.

6.2.15 Display Needs for Random IFR Route Operation

It is recommended that development be started immediately on a means of readily calling up on ATC radar indicators, geographical locations or waypoints defined by latitude and longitude, for temporary display as part of a



WHEN COURSE GUIDANCE IS AVAILABLE

FIGURE 7.2.12A. MISSED APPROACH CROSS SECTION, Par. 274. (TERPS)

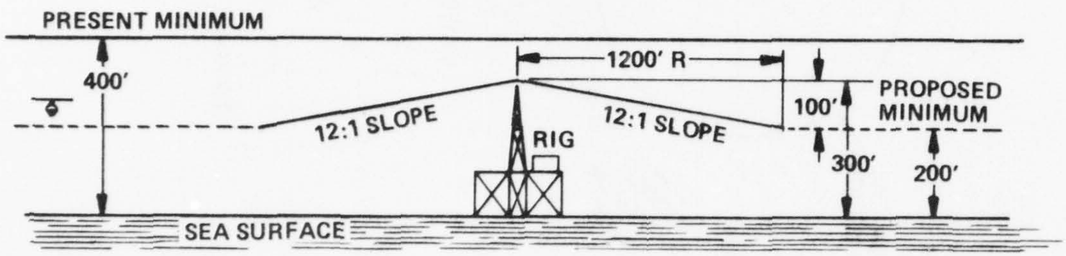


Figure 6.2.13A

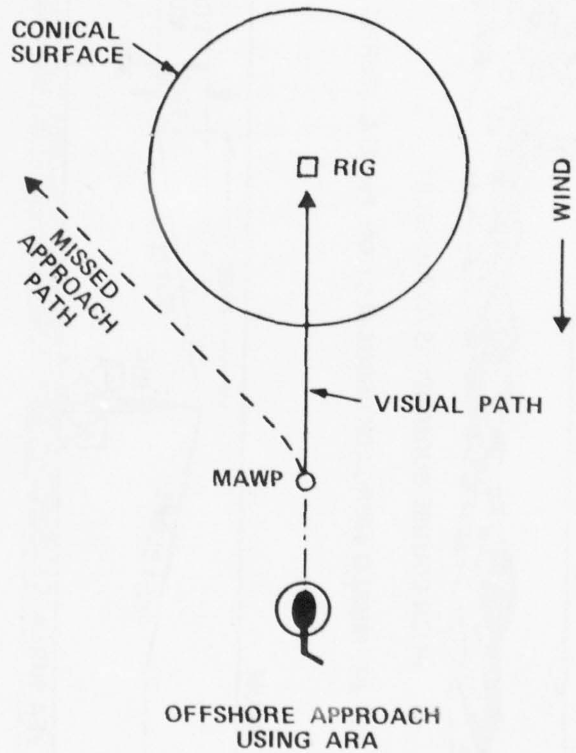


Figure 6.2.13B Plan view of offshore point-in-space approach

video map, but on an as-needed basis. Call-up may be either from flight-plan or manual input. The capability to connect such displayed waypoints with computer-generated video lines should also be implemented.

6.2.16 Low-Altitude Military Routes

It is recommended that the FAA establish and publicize several "800" toll-free long-distance telephone numbers which pilots (particularly in remote areas) could call to obtain information on the current status of activity on low-altitude military training routes.

6.2.17 Low-Conflict VTOL Route Concept

It is recommended that the low-conflict route concept described in Section 2 of this report be evaluated in high-density simulation of offshore traffic to determine its possible applicability in ground-based and distributed-management ATC systems.

6.2.18 Propagation

It is recommended that high-angle ionospheric and surface wave propagation be investigated by the FAA in order to determine whether either or both can meet the offshore and remote area helicopter communications or surveillance requirements, and whether it is economically and operationally feasible to employ one or the other for this purpose.

6.2.19 Navigation Equipment Checks

On the assumption that LORAN C will be approved for domestic navigation, it is recommended that the FAA establish criteria for periodic checks of LORAN C avionics, in a manner similar to the VOR avionics checks presently required by Federal Air Regulation 91.25.

6.2.20 Approach Metering

It is recommended that the adoption of approach metering be expedited at major terminal airports in order to reduce the length of low-altitude/CTOL vector patterns and thus leave more room for low-altitude helicopter patterns.

6.2.21 OTH Communications

In providing additional A/G communications for OTH traffic, it is recommended that consideration be given to the following alternatives, in the order listed:

1. Additional RCAG facilities, linked to ATC facilities via land lines, microwave, VHF troposcatter, or satellite repeater, with VHF link between RCAG and aircraft.
2. Air-to-Air VHF relay or repeater.
3. Landline Link between ATC facility and company radio operator, HF link between radio operator and aircraft.
4. Direct HF between ATC facility and aircraft, using Selcal and Calsel to avoid need for continuous listening watch on channel.

6.2.22 OTH Separation Assurance

It is recommended that the following short-term alternatives for maintaining separation be considered, in the order listed:

1. Procedural control, after providing controllers with refresher training in nonradar control procedures as necessary.
2. Remote SSR installation linked to ATC facility via land lines or microwave.

6.3 Long-Term Recommendations

6.3.1 OTH Separation Assurance

It is recommended that the following long-term alternatives for maintaining separation be considered, in the order listed:

1. HF data link in aircraft, with data link and microprocessor in ATC facility to interrogate aircraft on roll-call basis and decode and display aircraft identity, position, and altitude for controllers.
2. Distributed-management ATC concept using one-way traffic lanes, A/A communications, and CDTI (cockpit-displayed traffic information).

6.3.2 NAVSTAR/GPS

If the General Positioning System (GPS) continues into full implementation over the next decade, and if commercially affordable airborne equipment can be produced, it is possible that the higher accuracy of GPS will lead to its widespread future use for domestic as well as offshore flight operations. It is recommended that the FAA follow closely the technical progress of GPS, for possible future civil application.

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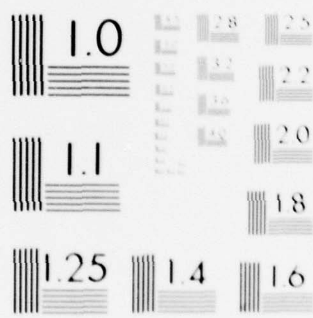

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APPENDIX A

TECHNICAL FACTORS AFFECTING OVER-THE-HORIZON SYSTEMS

VERY HIGH FREQUENCY (VHF) AND ULTRA HIGH FREQUENCY (UHF) BANDS

The very high frequency (VHF) band is defined as that portion of the radio frequency spectrum which lies between 30 and 300 MHz (10 to 1 meter wavelengths). Above the VHF band, and extending to 3,000 MHz (3.0 GHz) is the ultra high frequency band (1 to .01 meter wavelengths). Since the wavelengths associated with VHF and UHF signals are relatively short, the ionosphere normally is unable to refract these signals back to earth. During periods of intense sunspot activity or sporadic E, however, ionospheric propagation may occur for signals with frequencies in the lower portion of the VHF band (30 to 60 MHz). However, in general, ionosphere reflections may be assumed to be absent for radio frequencies above approximately 30 MHz. Thus, propagation in the VHF and UHF regions of the spectrum is generally along line-of-sight paths. Surface waves at VHF and UHF frequencies are so rapidly attenuated that they are of no practical value.

Since only a complete analysis of the propagation characteristics of VHF and UHF waves can determine the suitability of using frequencies above 30 MHz for offshore and some remote area helicopter operations, this section provides such an analysis.

SPACE WAVES

Useful propagation is achieved with signals at VHF or UHF frequencies by means of the space wave. Space waves travel through the earth's troposphere (first 16 km (10 miles) of the earth's atmosphere) to reach the receiver's antenna. There are primarily two ways for the energy of a space wave to travel in order to reach the receiver's antenna (see Figure A-1). The ray traveling directly from the transmitter to the receiver is called a "direct wave". The ray which reaches the receiver by way of a reflection from the earth's surface is called a "ground-reflected wave." However, it should also be noted that space wave energy may reach a receiver by way of refractions or reflections

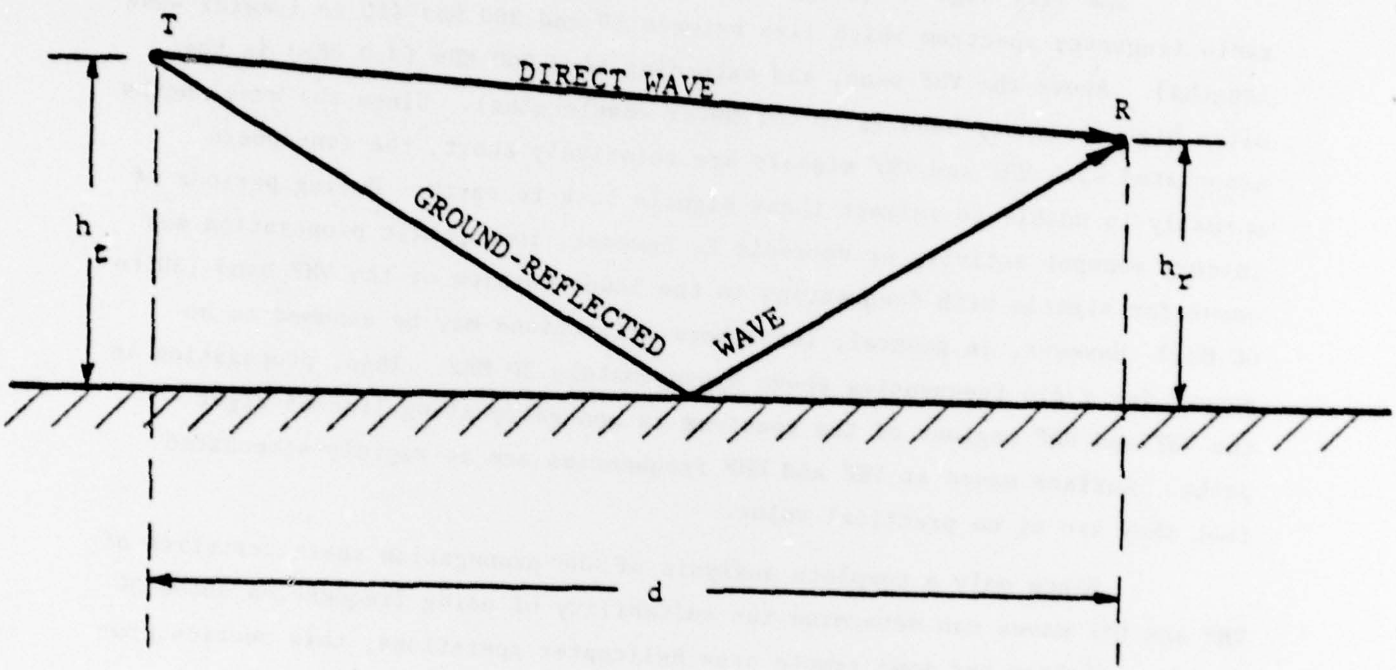

Figure A-1. The space wave consists of either, or both, the direct wave and the ground-reflected wave.

which result from variations in the electrical characteristics of the troposphere. Then, too, because of the relationship between the wave lengths involved and material objects, optical phenomena such as diffraction may be an important consideration with respect to the propagation of space waves. Finally, the surface wave associated with propagation at HF frequencies is rapidly attenuated in the VHF and UHF bands, and, as such, plays no part in the transmission of radio waves for communication purposes in the VHF and UHF bands.

FIELD STRENGTH OF SPACE WAVES

The field strength of a space wave at the receiving antenna is the vector sum of the fields from the direct wave and the ground-reflected wave. For space-wave propagation over an ideal flat earth, it can be shown (see, for example, Terman (1955)) that the field strength E at the receiver is given by the following equation:

$$E = A \frac{2E_o}{d} \sin \frac{2\pi h_t h_r}{\lambda d} \qquad \text{(A-1)}$$

where:

E = field strength at the receiver

E_o = field intensity produced at unit distance from the transmitter when the earth is absent

d = distance from the transmitting antenna to the receiving antenna

λ = wavelength of the space wave

h_t = height of the transmitting antenna

h_r = height of the receiving antenna

A = ground loss factor (=1 for free space)

To use Equation A-1 it is assumed that the amplitudes of the direct wave and ground-reflected wave at the receiving antenna are of equal magnitude while generally differing in phase. From using Equation A-1, an example of variations in signal strength as a function of distance from a hypothetical transmitter is shown in Figure A-2. The maximum field strength of these oscillations is twice the free-space value, and it occurs when the direct and ground-reflected waves add in phase.

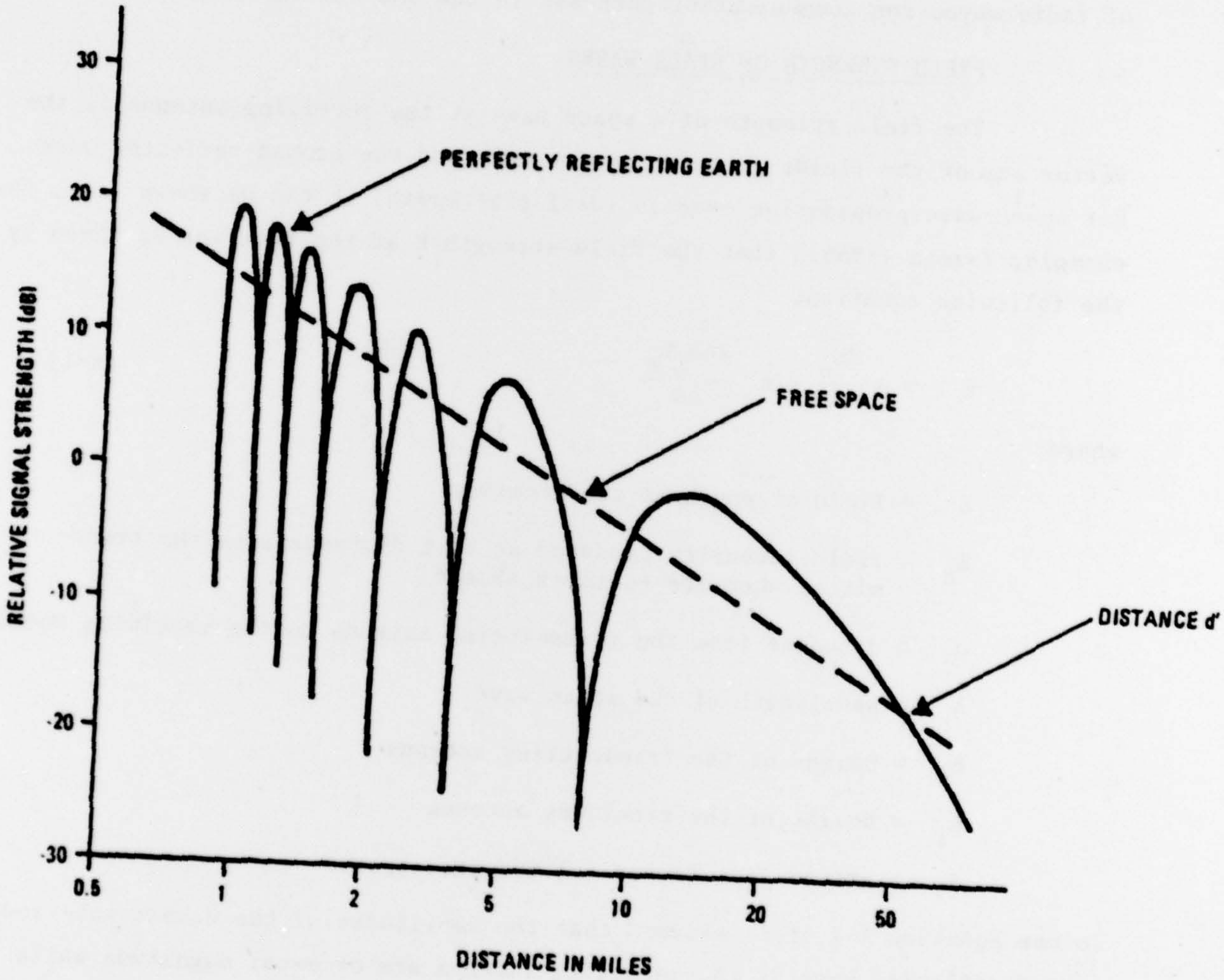

Figure A-2 Variation in field strength as a function of distance over a smooth, perfectly-reflecting earth. Distance d' is the distance beyond which the direct and surface-reflected waves are out of phase.

The field strength varies about the free-space value of distances up to where the phase angle between the direct and ground-reflected components is greater than 30 degrees. When the phase angle is less than 30 degrees for relative larger distances, the sine of the phase angle can be replaced by the angle. Hence Equation A-1 becomes:

$$E = \frac{4\pi h_t h_r}{\lambda d} A \frac{E_o}{d} = A \frac{4\pi h_t h_r}{\lambda d^2} E_o \qquad \text{(A-2)}$$

for phase angles of less than 30 degrees. Thus, while the field strength decreases inversely proportional to the distance when the phase angle is large, for distances where the phase angle is small, the field strength becomes inversely proportional to the square of the distance.

EFFECTS DUE TO THE CURVATURE OF THE EARTH

As seen in Figure A-3, one effect of the earth's curvature is to change the effective antenna heights. This, in turn, changes the location and number of the maxima and minima in the space-wave radiation pattern (see Figure A-2). From Equation A-2 it can be seen that the reduction in the effective heights acts to reduce the distance beyond which the direct and ground-reflected rays are out of phase, and so, everything else being equal, the field strength should drop off more rapidly than in the case of the flat-earth model.

A second effect due to earth curvature, however, must also be taken into account. Because of the earth's curvature, the reflected ray diverges, and as a result, becomes weaker than the direct ray. This produces a situation wherein, for everything else being equal, the field strength of the space wave is significantly greater than for the flat-earth case.

For the two effects noted above, when the direct path clears the radio horizon, the reduction in distance d' (Figure A-2) and the increase in field strength due to the divergence of the surface-reflected ray, tend to cancel. As such, the field strength at large distances is still given by Equation A-2.

SURFACE ROUGHNESS

GENERAL

When surface roughness (as measured relative to the wavelengths employed) increases, the effective reflection coefficient decreases in magnitude. To quantify surface roughness, refer to Figure A-4. For this case:

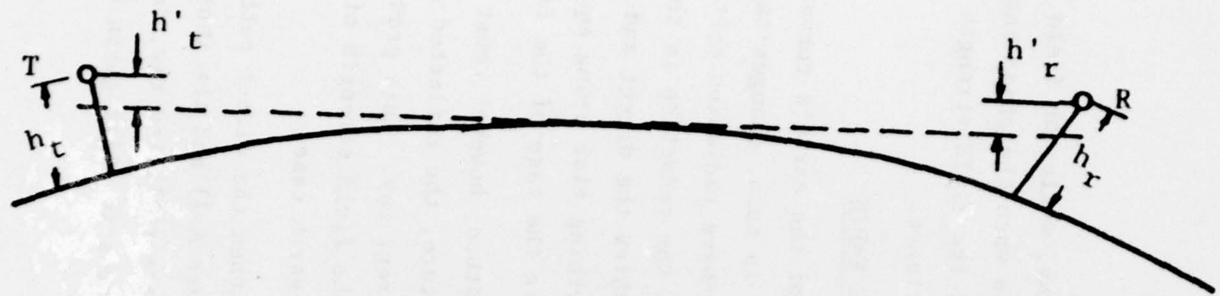

Figure A-3. One effect of earth curvature is to change the effective heights of the transmit and receive antennas.

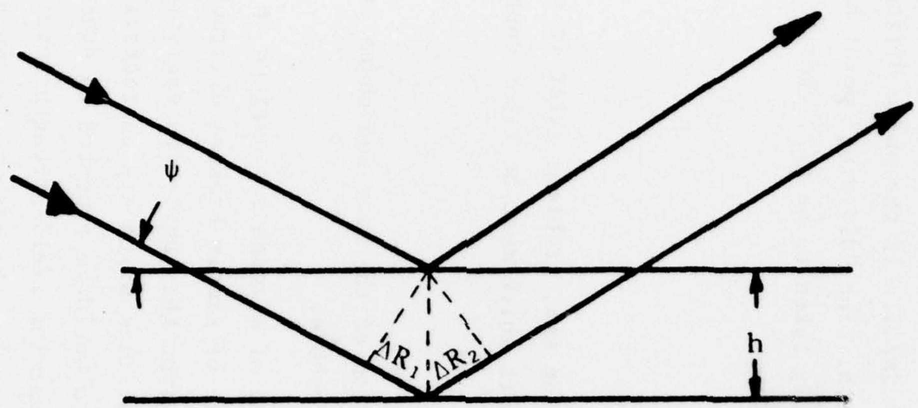

Figure A-4. The Phase difference ΔR between rays reflected from two levels is given by the sum of ΔR_1 and ΔR_2

$$\Delta R = \Delta R_1 + \Delta R_2 = 2h \sin \psi \qquad \text{(A-3)}$$

where:

ΔR = path difference between two rays

h = height of an irregularity of the surface

ψ = the grazing angle

The phase difference between the two rays (see Kerr (1964), p. 420) is

$$k\Delta R = \frac{4\pi h}{\lambda} \sin \psi \qquad \text{(A-4)}$$

where $k\Delta R$ is the phase difference ($k = 2\pi/\psi$). If the phase difference is small, the surface is effectively smooth. The "dividing" point between a smooth and a rough surface is frequently taken to be $\pi/2$. For this value a smooth surface is then defined as follows:

$$h \sin \psi < \frac{\lambda}{8} \qquad \text{(A-5)}$$

SEA SURFACE

With specific reference to the sea, problems exist in analyzing the effects due to a rough surface. Factors which must be taken consideration include:

1. Local diffraction effects;
2. The irregular distribution of the size and shape of waves;
3. The effect of foam and bubbles.

While a rigorous statistical treatment of a rough sea surface is preferred, a valid alternative appears to bethe use of simple Fresnal diffraction theory (Kerr (1964), p. 412). Regardless, given the short-time variations in the position and size of surface irregularities which are characteristic of a rough sea, reflections from such a sea would be expected to exhibit -- and do exhibit -- continuously and rapidly varying field-strength levels. While such effects are observed for meterwave signals, the effects are much more pronounced for wavelengths at the upper end of the UHF band. At 10 cm (3,000 MHz), for example, echoes from a moderately rough sea show violent fluctuations of up to 5 or 10 dB (Kerr (1964), p. 420).

In sum, as the roughness of the sea surface increases, increasingly large variations can be expected in the field-strength levels of the VHF and UHF signals propagating over such a surface.

THE SHADOW (OR DIFFRACTION) ZONE

When the receive terminal lies beyond the radio horizon -- (see Figure A-5) that is, in the so-called shadow, or diffraction zone -- the signal received is the sum of several components that travel different paths. Included are contributions due to:

1. Diffraction (depending on the roughness of the surface);
2. Turbulence in the troposphere (small irregularities in the refractive index produce scattering);
3. Gradual variations in the refractive index (such variations produce scattered components in much the same way as does turbulence).

Propagation in the shadow zone is referred to as extended-range propagation, and this phenomenon tends to be insensitive to antenna height (especially to heights of several hundred feet). Further, to a first approximation, the extended range phenomenon is independent of frequency.

FADING

The strength of the received space-wave signal is the sum of several components which travel different paths. As such, the intensity of the signal is very sensitive to changes in the relative phases of these components, and in particular, to effects produced by changing tropospheric conditions. The variations in the intensity of the received signal, as a function of time, which are produced by the interference of the various signal components are known as fading.

Since fading depends primarily on the meteorological conditions in the troposphere, the extent and character of fading over any given path exhibits significant variations over time. Thus, fading can be deep or shallow, and rapid or slow, in nature.

Because phase relationships are involved, the intensity of a signal on which fading is evident, is frequency dependent.

Finally, fading is most pronounced when, for the distance involved, the received signal is considerably weaker than the free-space value. As such, signals near the radio horizon and in the shadow zone tend to exhibit the greatest amount of fading, while signals which arrive over good optical paths generally exhibit little fading.

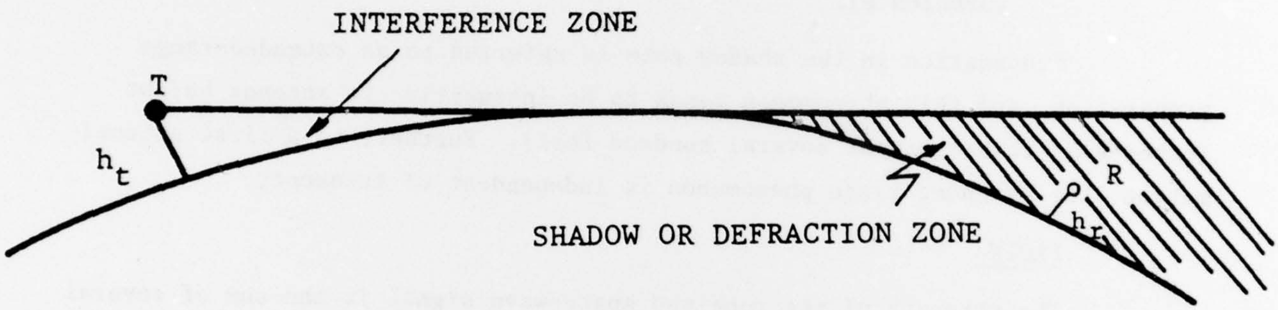

Figure A-5. Diagram showing location of the interference and shadow zones.

DUCTING

When, in a given region of the lower atmosphere, the index of refraction decreases rapidly with height, radiation of a sufficiently short wavelength may become trapped in this region. Once trapped, the radiation may be guided around the curved surface of the earth in much the same manner as it would be guided within a waveguide. These regions or layers in the atmosphere where the index of refraction decreases rapidly with height are known as "ducts," and an example of such a phenomenon is given in Figure A-6.

When propagation exists, signals can travel over extended distances, with low attenuation (less than 5 dB per 100 miles) for line-of-sight paths, and, as such, diffraction-zone propagation no longer applies. Further, because ducting is a waveguide phenomenon, a cutoff wavelength exists which is related to duct height as follows:

$$\lambda_{max} = 0.014\ d^{3/2} \qquad \text{(A-6)}$$

where λ_{max} = the cutoff wavelength in centimeters

and d = the duct height in feet.

Conditions for the formation of ground-based ducts (Figure A-6A) are especially favorable over water, and they are thought to be present at almost all times in the trade-wind belts. When ducts to occur, they generally range from a few tens of feet to 500 or 600 feet in height. From Equation A-6, and for a duct height of 600 feet, the cutoff wavelength is cm (~46 MHz). Thus, ducting can effect the propagation of radio waves throughout the VHF and UHF bands, though this type of propagation is observed most frequently for wavelengths less than 1 m (300 MHz; see Kerr (1964), p. 821).

For reasons due to the sporadic occurrence of most ducts, and because both the transmitter and the receiver must be within the duct to effect communications, duct propagation is not considered to be useful for current FAA applications.

POWER REQUIREMENTS AND RANGE LIMITATIONS

The following analyses are presented in order to investigate the range limitations and power requirements for VHF and UHF signals. Table A-1 contains the assumptions used in the analyses performed below.

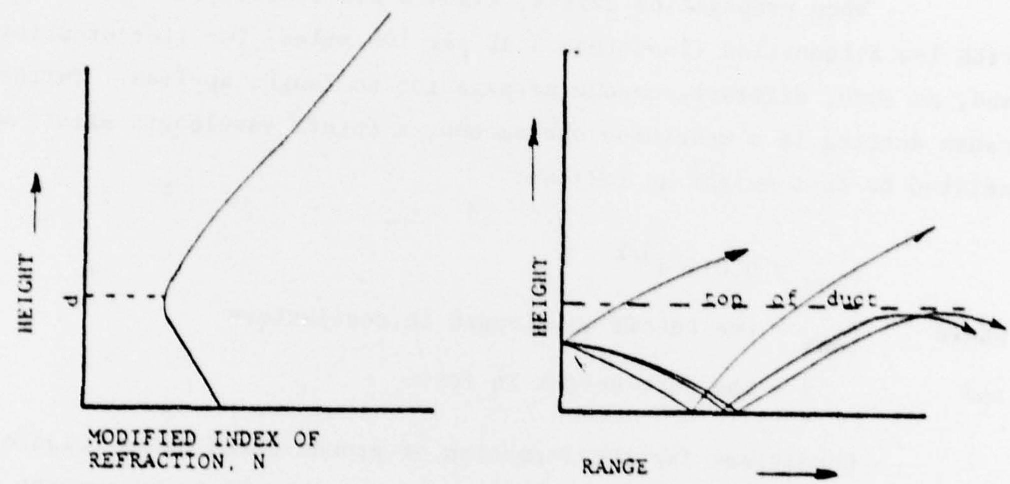

Figure A-6 (A) An example of a surface duct.
(B) Ray paths within the surface duct.

TABLE A-1

ASSUMPTIONS USED IN ANALYSES TO EXAMINE POWER REQUIREMENTS AND RANGE LIMITATIONS OF VHF AND UHF SIGNALS

OPERATING FREQUENCY:	150 MHz
TRANSMITTER ANTENNA GAIN: (on helicopter)	2 dBi
HEIGHT OF TRANSMITTER ANTENNA:	30 m
TRNSMITTER LINE LOSS:	0.5 dB
RECEIVER ANTENNA GAIN: (on shore)	2 dBi
HEIGHT OF RECEIVER ANTENNA:	100 m
RECEIVER LINE LOSS:	7.5 dB
FM RECEIVER SENSITIVITY (20 dB $\frac{S + N}{N}$):	-120 dBm

The distance from an antenna to its radio horizon is determined as follows:

$$d = (2a_e h)^{1/2} \tag{A-7}$$

where: d = distance from antenna to its radio horizon in km

h = antenna height in km

a_e = effective earth radius in km (8400 km is a nominal value).

The "line-of-sight" distance for a communications link is equal to the sum of the horizon distances for the individual transmitter and receiver antenna heights. Using Equation A-7 for antenna heights of 30 meter and 100 meters, the "line-of-sight" distance is 63 km (34 nmi). This is significantly less than the 300 nmi range which may be required for offshore helicopter operations, and effectively demonstrates the inability of unassisted (i.e., no use of repeaters) VHF/UHF operation to support the FAA's requirements in the offshore environment, as well as in some remote areas.

Regardless of the result obtained above, it is instructive to examine the power requirements for effective "line-of-sight" communications over distances up to 63 km.

Using Equation B-2* for the parameters given in Table A-1, and for a "line-of-sight" distance of 63 km, the loss in field strength is calculated to be about 122 dB. Since the required signal strength at the receiver antenna is -114.5 dBm (-120 + 7.5 - 2), and since the transmitter's antenna has a gain of 2 dB while the transmitter line has a 0.5 dB loss, the minimum required output power of the transmitter for effective communications is:

7 dBm (122 - 2 + 1.5 - 114.5).

Thus, the required output power of the transmitter is approximately 5 milliwatts. This example demonstrates the ease by which VHF/UHF communications can be established at low power levels over line-of-sight distances.

Beyond the radio horizon, the transmission loss of a VHF/UHF signal increases because of diffraction, and the power levels required to maintain effective communications increase significantly. For further information on

*Equation A-2 must be multiplied by a factor of $\frac{\lambda}{4\pi}$ to account for the frequency dependence of the transmission loss.

defraction attenuation, the reader is referred to International Radio Consultative Committee (CCIR) literature. Suffice it to say that it is not feasible to use unassisted VHF/UHF links for all-weather offshore communications or surveillance systems with a required range of 300 nmi.